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RADIOLOGICAL HEALTH HANDBOOK

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Cincinnati, Ohio

November 1954

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RADIOLOGICAL HEALTH HANDBOOK

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PREFACE

In 1950 a mimeographed set of data was prepared for the students attending the Radiological Health Training Courses offered by the Public Health Service at the Environmental Health Center in Cincinnati, Ohio. These data were so useful for both the students and staff they were extended, reorganized and assembled in 1951 into a temporary booklet. The cordial response to such a compilation of data, the addition of more and varied courses in the field of radiological health, the exponential progress in the theory and use of atomic energy, and the student recommendations inspired the issuance of the 1952 edition of the Radiological Health Handbook.

The demand for this handbook was greater than anticipated and exceeded our supply. To comply with the many requests for this compilation of radiological data, our 1952 publication was modified and released again in 1953. The 1954 edition was stimulated by the release of a revision of the table of isotopes. This edition of the Handbook includes the revised table of isotopes and utilizes the more recent data from this table to calculate other entries in the handbook.

Appreciation is expressed to all of the users of the Handbook who have called attention to errors and omissions. Such procedures are highly desirable and it is hoped that recipients of this handbook will continue to transmit suggestions for increasing the accuracy in presenting the most reliable data selected for publication.

Grateful acknowledgment of an indebtedness to D. J. Nelson, Jr., Dr. V. E. Archer, and H. J. L. Rechen, all former members of the Radiological Health Training Section is hereby made for their continued interest and consistent submission of material and recommendations for the improvement of this compilation of data. The encouragement and support from Mr. J. G. Terrill, Jr., Chief, Radiological Health Program for the Bureau of State Services of the United States Public Health Service, is likewise recognized as an important factor in expediting the 1954 edition and in making possible this second printing.

Although the individual contributions to this handbook are too numerous to list in detail, a special acknowledgment is made to those whose kind permission allowed reproduction of material from their files and publications, namely: Dr. Karl Z. Morgan, Dr. Austin M. Brues, Dr. Edwin G. Williams, J. M. Hollander, Dr. I. Perlman, and Dr. Glenn T. Seaborg. Sincere appreciation is likewise expressed to the following organizations for furnishing and permitting the reprinting of certain data as acknowledged within this edition: National Bureau of Standards, Atomic Energy Commission, and Stanford Research Institute.

Cincinnati, Ohio
November 18, 1954

SIMON KINSMAN

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GLOSSARY

ABSORPTION: The process by which the number of particles or quanta in a beam of radiation is reduced or degraded in energy as it passes through some medium. The absorbed radiation may be transformed into mass, other radiation, or energy by interaction with the electrons or nuclei of the atoms upon which it impinges.

ABSORPTION COEFFICIENT: Fractional decrease in the intensity of a beam of radiation per unit thickness (linear absorption coefficient), per unit mass (mass absorption coefficient), or per atom (atomic absorption coefficient) of absorber.

ACCELERATOR: A device for imparting large kinetic energy to charged particles, such as electrons, protons, deuterons, and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator, and Van de Graaf electrostatic generator.

ACTIVATED WATER: A transient chemically reactive state created in water by absorbed ionizing radiations.

ACTIVATION ANALYSIS: A method of chemical analysis, especially for small traces of material, based on the detection of characteristic radionuclides following a nuclear bombardment.

ACTIVATION ENERGY: The energy necessary to cause a particular reaction to begin. Nuclear: The amount of outside energy which must be added to a nucleus before a particular nuclear reaction will begin. Chemical: The amount of outside energy necessary to activate an atom or molecule so as to cause it to react chemically.

ACTIVITY: (See RADIOACTIVITY).

ACUTE EXPOSURE: Term used to denote radiation exposure of short duration.

ADSORPTION: The adhesion of one substance to the surface of another.

AIR DOSE: X-ray or gamma ray dose expressed in roentgens delivered at a point in free air. In radiologic practice it consists of the radiation of the primary beam and that scattered from surrounding air.

AIR WALL IONIZATION CHAMBER (X- or Gamma Rays): Ionization chamber in which the materials of the wall and electrodes are so selected as to produce ionization essentially equivalent to that in a free air ionization chamber. This is possible only over limited ranges of photon energies. Such a chamber is more appropriately termed an air-equivalent ionization chamber.

ALPHA PARTICLE: A helium nucleus, consisting of two protons and two neutrons, with a double positive charge. Its mass is 4.002677 mass units.

ALPHA RAY: Stream of fast-moving helium nuclei; a strongly ionizing and weakly penetrating radiation.

ALVEOLI: The terminal air sacs of the lungs.

AMINO ACID: An organic acid; the building blocks in the formation of proteins.

AMPERE: Practical unit of current; the flow of 1 coulomb/sec. Abbreviated: amp.

AMPLIFICATION: As related to radiation detection instruments, the process (either gas, electronic, or both) by which ionization effects are magnified to a degree suitable for their measurement.

ANEMIA: Deficiency of blood as a whole, or deficiency in the number of the red corpuscles or of the hemoglobin.

ANION: Negatively charged ion.

ANNIHILATION RADIATION: Photons produced when an electron and a positron unite and cease to exist. The annihilation of a positron-electron pair results in the production of two photons, each of at least 0.51 Mev energy.

ANODE: Positive electrode; electrode to which negative ions are attracted.

ANOXIA: Oxygen deficiency; a condition which results from a diminished supply of oxygen to the tissues.

ASSOCIATED CORPUSCULAR EMISSION: The full complement of secondary charged particles (usually limited to electrons) associated with an x-ray or gamma-ray beam in its passage through air. The full complement of electrons is obtained after the radiation has traversed sufficient air to bring about equilibrium between the primary photons and secondary electrons. Electronic equilibrium with the secondary photons is intentionally excluded.

ATOM: Smallest particle of an element which is capable of entering into a chemical reaction.

ATOMIC NUMBER: Number of protons in the nucleus, hence the number of positive charges on the nucleus. Also the number of electrons outside the nucleus of a neutral atom. Symbol: Z.

ATOMIC WEIGHT: Relative weight of the atom of an element compared with the weight of one atom of oxygen taken as 16; hence, a multiple of 1/16 the weight of an atom of oxygen.

ATROPHY: Wasting away or diminution in the size of cell, tissue, organ or part from defect or failure of nutrition.

ATTENUATION: The reduction of intensity of radiation due to an interposed medium. (Particle attenuation, energy attenuation).

ATTENUATION FACTOR: The ratio of the incident intensity of radiation to the transmitted intensity.

AUTORADIOGRAPH: Record of radiation from radioactive material in an object, made by placing its surface in close proximity to a photographic emulsion.

AVALANCHE: The multiplicative process in which a single charged particle accelerated by a strong electric field produces additional charged particles through collision with neutral gas molecules. This cumulative increase of ions is also known as Townsend ionization or a Townsend avalanche.

AVERAGE LIFE (MEAN-LIFE): The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half-life

AVOGADRO'S NUMBER (6.03×10^{23}): Number of atoms in a gram-atomic weight of any element; also the number of molecules in the gram-molecular weight of any substance.

BACKGROUND RADIATION: Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

BACKSCATTERING: The process of scattering or reflecting into the sensitive volume of a measuring instrument radioactive radiations originally having no positive component of motion in that direction. It is dependent, therefore, on the nature of the mounting material, the nature of the sample, the type and energy of the radiations, and the particular geometrical arrangement.

BARN. Unit expressing the probability of a specific nuclear reaction taking place in terms of cross-sectional area. Numerically it is $10^{-24}cm^2$.

BETA PARTICLE: Charged particle emitted from the nucleus of an atom and having a mass and charge equal in magnitude to those of the electron.

BETA RAY: A stream of high speed electrons of nuclear origin more penetrating but less ionizing than alpha rays; a stream of high-speed electrons.

BETATRON: A device for accelerating electrons by means of magnetic induction.

BINARY SCALER: A scaler whose scaling factor is two per stage. (See SCALER).

BINDING ENERGY: The energy represented by the difference in mass between the sum of the component parts and the actual mass of the nucleus.

BIOLOGIC EFFECTIVENESS OF RADIATION: (See RELATIVE BIOLOGICAL EFFECTIVENESS OF RADIATION).

BIOLOGICAL HALF LIFE: The time required for the body to eliminate one half of an administered dose of any substance by regular processes of elimination. This time is approximately the same for both stable and radioactive isotopes of a particular element.

BLOOD DYSCRASIA: Any persistent change from normal of one or more of the blood components.

BONE MARROW: Soft material which fills the cavity in most bones; it manufactures most of the formed elements of the blood.

BONE SEEKER: Any compound or ion which migrates in the body preferentially into bone.

BORON COUNTER TUBE: A counter tube filled with boron trifluoride (BF_3) and/or having electrodes coated with boron or boron compounds used for detecting slow neutrons by the (n, α) reaction of B^{10}.

BREEDER: (See CONVERTER).

BREMSSTRAHLUNG: Secondary photon radiation produced by deceleration of charged particles passing through matter.

BUILD UP FACTOR: The ratio of the intensity of x or gamma radiation (both primary and scattered) at a point in an absorbing medium to the intensity of only the primary radiation. This factor has particular application for "broad beam" attenuation. "Intensity" may refer to energy flux, dose, or energy absorption.

CALIBRATION: Determination of variation from standard, or accuracy, of a measuring instrument, to ascertain necessary correction factors.

CALORIE (Gram-Calorie): Amount of heat necessary to raise the temperature of one gram of water 1°C (from 14.5°C to 15.5°C). Abbreviation: cal.

CANCER: Any malignant neoplasm. (Popular usage).

CAPILLARY: A small thin-walled blood vessel connecting an artery with a vein.

CAPTURE CROSS SECTION: The probability that a nucleus will capture an incident particle. The unit of cross section is commonly the barn (10^{-24}cm^2).

CAPTURE, RADIATIVE: The process by which a nucleus captures an incident particle and loses its excitation energy immediately by the emission of gamma radiation.

CARCINOGENIC: Capable of producing cancer.

CARCINOMA: Malignant neoplasm composed of epithelial cells, regardless of their derivation.

CARRIER: 1. A quantity of an element which may be mixed with radioactive isotopes of that element giving a ponderable quantity to facilitate chemical operations. 2. A substance in ponderable amount which when associated with a trace of another substance will carry the trace with it through a chemical or physical process, especially a precipitation process. If the added substance is a different element from the trace, the carrier is called a non-isotopic carrier.

CARRIER FREE: An adjective applied to one or more radioactive isotopes of an element in minute quantity, essentially undiluted with stable isotope carrier.

CATARACT: A clouding of the crystalline lens of the eye, which obstructs the passage of light.

CATHODE: Negative electrode; electrode to which positive ions are attracted.

CATION: Positively charged ion.

CELL (Biological): The fundamental unit of structure and function in organisms.

CHAIN REACTION: Any chemical or nuclear process in which some of the products of the process or energy released by the process are instrumental in the continuation or magnification of the process.

CHARACTERISTIC (DISCRETE) RADIATION: Radiation originating from an atom following removal of an electron or excitation of the nucleus. The wavelength of the emitted radiation is specific depending only on the element concerned and the particular energy levels involved.

CHEMICAL (ISOTOPIC) EXCHANGE: A process in which atoms (isotopes) of the same element in two different molecules exchange places.

CHRONIC EXPOSURE: Term used to denote radiation exposure of long duration, by fractionation or protraction. (See DOSE, FRACTIONATION and DOSE, PROTRACTION).

CLINICAL: Pertaining to the observed symptoms and cause of disease.

CLOUD CHAMBER: A device for observing the paths of ionizing particles, based on the principle that super-saturated vapor condenses more readily on ions than on neutral molecules.

COINCIDENCE: The occurrence of ionizing events in one or more detectors simultaneously or within an assignable time interval, as a result of the passage of a single particle or of several generically related particles.

COINCIDENCE CORRECTION: Mathematical calculation to correct observed count to the count free of coincidence losses.

COLLIMATOR: A device for confining the elements of a beam within an assigned solid angle.

COLLISION: Encounter between two sub-atomic particles (including photons), which changes the existing momentum and energy conditions. The products of the collision need not be the same as the initial systems.

COLLISION, ELASTIC: Collision in which kinetic energy and momentum of each colliding system are conserved.

COLLISION, INELASTIC: Collision in which at least one system gains internal excitation energy at the expense of the total kinetic energy of their center-of-gravity motion.

COMPTON EFFECT: An absorption effect observed for x- and gamma radiation in which the incident photon interacts with an orbital electron of the absorber atom to produce a recoil electron and a photon of energy less than the incident photon.

COMPOUND: Pure substance composed of two or more elements combined in a fixed and definite proportion by weight.

CONDENSER R-METER: An instrument consisting of an "air-wall" ionization chamber together with auxiliary equipment for charging and measuring its voltage; it is used as an integrating instrument for measuring the quantity of x- or gamma radiation in roentgens. (See IONIZATION CHAMBER).

CONSERVATION OF MASS-ENERGY: Energy and mass are interchangeable in accordance with equation $E = mc^2$, where E is energy, m is mass, and c is velocity of light.

CONTACT RADIATION THERAPY: X-ray therapy with specially constructed tubes in which the target-skin distance is very short (less than 2 cm.). The voltage is usually between 40 and 60 kv.

CONTAMINATION, RADIOACTIVE: Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm may be in vitiating the validity of an experiment or a procedure, or in actually being a source of danger to personnel.

CONVERTER: A nuclear reactor that converts fertile atoms into fuel by neutron capture. Two different ways of using the words converter and breeder are in use at present: 1. A converter is a reactor that uses one kind of fuel and produces another (e. g. consumes U^{235} and produces Pu from U^{238}). 2. A breeder is a converter that produces more fissionable atoms than it consumes.

CORE: In a nuclear reactor, the region containing the fissionable material. In a heterogeneous reactor, the region containing fuel-bearing cells.

CORPUSCLE: A blood cell.

COSMIC RAYS: Particulate and electromagnetic radiations which originate in outer space.

COULOMB: Unit of electrical charge in the practical system of units. A quantity of electricity equal to 3×10^9 electrostatic units of charge.

COUNT (Radiation measurements): The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term often is erroneously used to designate a disintegration, ionizing event or voltage pulse.

COUNTING RATE METER: A device which gives a continuous indication of the average rate of ionizing events.

CRITICAL SIZE: For a fissionable material, the minimum amount of a material which will support a chain reaction.

CROSS SECTION, NUCLEAR: The probability that a certain reaction between a nucleus and an incident particle or photon will occur. It is expressed as the effective "area" that the nucleus presents for the reaction. (See BARN).

CUMULATIVE DOSE (Radiation): The total dose resulting from repeated exposures to radiation of the same region, or of the whole body.

CURIE: That quantity of a radioactive material having associated with it 3.7×10^{10} disintegrations per second.

CYCLOTRON: A device for accelerating charged particles to high energies by means of an alternating electric field between electrodes placed in a constant magnetic field.

DECADE SCALER: A scaler whose scaling factor is a power of ten. (See SCALER).

DECAY, RADIOACTIVE: Disintegration of the nucleus of an unstable element by the spontaneous emission of charged particles and/or photons.

DECAY CONSTANT: The fraction of the number of atoms of a radioactive isotope which decay in unit time. Symbol: λ. (See DISINTEGRATION CONSTANT).

DECAY CURVE: A curve showing the relative amount of radioactive substance remaining after any time interval.

DECONTAMINATION FACTOR: The ratio of the amount of undesired radioactive material initially present to the amount remaining after a suitable processing step has been completed. Decontamination factors may refer to the reduction of some particular type of radiation, or of the gross measurable radioactivity.

DENSITOMETER: Instrument utilizing the photoelectric principle to determine the degree of darkening of developed photographic film.

DENSITY (Photographic): Logarithm of opacity of exposed and processed film. Opacity is the reciprocal of transmission; transmission is the ratio of transmitted to incident intensity. Density is used to denote the degree of darkening of photographic film.

DEPOLYMERIZATION: The breaking down of an organic compound into two or more less complex molecules.

DEPTH DOSE: The radiation dose delivered at a particular depth beneath the surface of the body. It is usually expressed as a percentage of surface dose or as a percentage of air dose.

DEUTERIUM: A heavy isotope of hydrogen having one proton and one neutron in the nucleus. Symbol: D or ${}_1H^2$.

DEUTERON: Nucleus of a deuterium atom, containing one proton and one neutron.

DIFFERENTIAL ABSORPTION RATIO: Ratio of concentration of an isotope in a given organ or tissue to the concentration that would be obtained, if the same administered quantity of this isotope were uniformly distributed throughout the body.

DIRECT RADIATION: All radiation coming from within an x-ray tube and tube housing except the useful beam.

DISINTEGRATION, NUCLEAR: A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved the process is characterized by a definite half-life.

DISINTEGRATION CONSTANT: The fraction of the number of atoms of a radioactive isotope which decay in unit time; λ in the equation $N = N_0e^{-\lambda t}$, where N_0 is the initial number of atoms present, and N is the number of atoms present after some time, t.

DOMINANT CHARACTER (Genetics): Of a pair of contrasted characteristics, the one which will appear in a hybrid resulting from cross-breeding of parents unlike with respect to that characteristic.

DOSE (DOSAGE): According to current usage, the radiation delivered to a specified area or volume or to the whole body. Units for dose specificatioh are roentgens for x- or gamma rays, reps or equivalent roentgens for beta rays. In radiology the dose may be specified in air, on the skin, or at some depth beneath the surface; no statement of dose is complete without specification of location. The entire question of radiation dosage units is under consideration by the International Congress of Radiology. (See RAD).

DOSE, FRACTIONATION: A method of administration of radiation in which relatively small doses are given daily or at longer intervals.

DOSE, PROTRACTION: A method of administration of radiation by delivering it continuously over a relatively long period at a low dosage rate.

DOSE RATE (DOSAGE RATE): Radiation dose delivered per unit time.

DOSE RATE METER: Any instrument which measures radiation dose rate.

DOSIMETER: Instrument used to detect and measure an accumulated dosage of radiation; in common usage it is a pencil size ionization chamber with a built-in self reading electrometer; used for personnel monitoring.

DYNE: The unit of force which, when acting upon a mass of one gram will produce an acceleration of one cm. per sec. per sec.

EDEMA: Presence of abnormally large amounts of fluid in the intercellular tissue spaces of the body, or part of the body.

EFFECTIVE ATOMIC NUMBER: A number calculated from the composition and atomic numbers of a compound or mixture. An element of this atomic number would interact with photons in the same way as the compound or mixture.

EFFECTIVE HALF LIFE: Time required for a radioactive element fixed in the tissues of an animal body to be diminished 50 per cent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half life} = \frac{\text{Biological half life} \times \text{Radioactive half life}}{\text{Biological half life} + \text{Radioactive half life}}$$

EFFICIENCY (Counters): A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so that it is well to make sure which factors (window transmission, sensitive volume, energy dependence, etc.) are included in a given case.

ELECTRODE: Either terminal of an electrical apparatus.

ELECTROMETER: Electrostatic instrument for measuring the difference in potential between two points. Used to measure change of electric potential of charged electrodes resulting from ionization produced by radiation.

ELECTROMOTIVE FORCE: Potential difference across electrodes tending to produce an electric current. Abbreviation: emf.

ELECTRON: Negatively charged particle which is a constituent of every neutral atom. Unit of negative electricity equal to 4.80 x 10^{-10} electrostatic units. Its mass is 0.000548 mass units.

ELECTRON CAPTURE: A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from a particular electron shell is designated as K-electron capture, L-electron capture, etc.

ELECTRON VOLT: A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of one volt. Larger multiple units of the electron volt are frequently used, viz: Kev, for thousand or kilo electron volts; Mev for million electron volts and Bev for billion electron volts. Abbreviation: ev.

ELECTROSCOPE: Instrument for detecting the presence of electric charges by the deflection of charged bodies.

ELECTROSTATIC FIELD: The region surrounding an electric charge in which another electric charge experiences a force.

ELECTROSTATIC UNIT OF CHARGE (STATCOULOMB): That quantity of electric charge which, when placed in a vacuum one cm. distant from an equal and like charge, will repel it with a force of one dyne. Abbreviated: esu.

ELEMENT: Pure substance consisting of atoms of the same atomic number, which cannot be decomposed by ordinary chemical means.

EMULSION, NUCLEAR: A photographic emulsion specially designed to permit observation of the individual tracks of ionizing particles.

ENDOERGIC REACTION: Reaction which absorbs energy.

ENDOTHERMIC REACTION: Reaction which absorbs energy specifically in the form of heat.

ENERGY: Capacity for doing work. Potential energy is the energy inherent in a mass because of its position with reference to other masses. Kinetic energy is the energy possessed by a mass because of its motion; cgs units: $gm\text{-}cm^2/sec^2$ or erg.

ENERGY DEPENDENCE: The characteristic response (of a radiation detector) to a given range of radiation energies (or wave lengths) as compared with the response of a standard free air chamber.

ENRICHED MATERIAL: 1. Material in which the relative amount of one or more isotopes of a constituent has been increased. 2. Uranium in which the abundance of the U^{235} isotope is increased above normal.

ENZYME: An organic compound, frequently a protein, that accelerates (catalyzes) specific transformations of material as in the digestion of foods.

EPIDERMIS: The outermost layer of cells of the skin.

EPILATION (DEPILATION): The temporary or permanent removal of hair.

EPITHELIUM: A term applied to cells that line all canals and surfaces having communication with external air and that are specialized for secretion in certain glands as the liver, kidneys, etc.

ERG: Unit of work done by a force of 1 dyne acting through a distance of one cm. Unit of energy which can exert a force of one dyne through a distance of one cm; cgs units: dyne-cm or gm-cm^2/sec^2.

ERYTHEMA: An abnormal redness of the skin, due to distension of the capillaries with blood. It can be caused by many different agents, e.g., heat, certain drugs, ultraviolet rays, ionizing radiation.

ERYTHROCYTE: A red blood corpuscle.

EUGENICS: The science which deals with the influences that improve the hereditary quality of the human race.

EXIT DOSE: Dose of radiation at surface of body opposite to that on which the beam is incident.

EXOERGIC: That which liberates energy.

EXOTHERMIC: That which liberates energy, specifically as heat.

EXTERNAL RADIATION: Exposure to ionizing radiation when the radiation source is located outside the body and the radiation must then penetrate into the deeper tissues.

EXTRAPOLATION IONIZATION CHAMBER: An ionization chamber with electrodes whose spacing can be adjusted and accurately determined to permit extrapolation of its reading to zero chamber volume.

FEATHER ANALYSIS: A technique for the determination of the range in aluminum of the beta particles of a radioelement by comparison of the absorption curve with the absorption curve of a reference series usually Bi^{210} (range-501 mg/cm^2).

FILM BADGE: A pack of photographic film used for approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or three films of differing sensitivity, and it may contain a filter which shields part of the film from certain types of radiation.

FILM RING: A film badge in the form of a finger ring.

FILTER (Radiology) Primary: A sheet of material, usually metal, placed in a beam of radiation to absorb, as far as possible, the less penetrating components. Secondary: A sheet of material of low atomic number relative to that of the primary filter, placed in the filtered beam of radiation to remove characteristic radiation produced by the primary filter.

FISSION: See NUCLEAR FISSION.

FISSION PRODUCTS: Elements or compounds resulting from fission.

FISSION YIELD: The percentage of fissions leading to a particular nuclide by direct formation and by decay of precursors.

FLUORESCENCE: The emission of radiation of particular wavelengths by a substance as a result of absorption of radiation of shorter wavelength. This emission occurs essentially only during the irradiation.

FLUORESCENT SCREEN: A sheet of material coated with a substance such as calcium tungstate or zinc sulfide which will emit visible light when irradiated with ionizing radiation.

FLUOROGRAPHY (PHOTOFLUOROGRAPHY): Photography of image produced on fluorescent screen by x- or gamma radiation.

FLUOROSCOPE: A fluorescent screen, suitably mounted with respect to an x-ray tube for ease of observation and protection, used for indirect visualization by means of x-rays of internal organs in the body or internal structures in apparatus or in masses of metal.

FOCAL SPOT (X-rays): The part of the target of the x-ray tube which is struck by the main electron stream.

FREE AIR IONIZATION CHAMBER: An ionization chamber in which a delimited beam of radiation passes between the electrodes without striking them or other internal parts of the equipment. The electric field is maintained perpendicular to the electrodes in the collecting region; as a result the ionized volume can be accurately determined from the dimensions of the collecting electrode and the limiting diaphragm. This is the basic standard instrument for x-ray dosimetry within the range of 5 to 400 Kv.

FREQUENCY: Number of cycles, revolutions, or vibrations completed in a unit of time.

FUEL ROD: A long, slender fuel assembly for nuclear reactor use.

FUSION: (See NUCLEAR FUSION).

GAMMA RAY: Short wavelength electromagnetic radiation of nuclear origin with a range of wave lengths from 10^{-9} to 10^{-12} cm, emitted from the nucleus.

GAS AMPLIFICATION: As applied to gas ionization radiation detecting instruments; the ratio of the charge collected to the charge produced by the initial ionizing event.

GAS FLOW COUNTER (Radiation): A counter in which an appropriate atmosphere is maintained in the counter tube by allowing a suitable gas to flow slowly through the sensitive volume.

GEIGER-MUELLER (G-M) COUNTER: Highly sensitive gas-filled radiation-measuring device which operates at voltages sufficiently high to produce avalanche ionization.

GEIGER REGION: In an ionization radiation detector, the operating voltage interval in which the charge collected per ionizing event is essentially independent of the number of primary ions produced in the initial ionizing event.

GEIGER THRESHOLD: Minimum voltage at which a Geiger-Mueller tube will indicate the presence of ionizing events.

GENE: Fundamental unit of inheritance which determines and controls hereditarily transmissible characteristics. Genes are arranged linearly at definite loci on chromosomes.

GENETIC EFFECT OF RADIATION: Inheritable changes, chiefly mutations, produced by the absorption of ionizing radiations. On the basis of present knowledge these effects are purely additive, and there is no recovery.

GENETICS: The branch of biology dealing with the phenomena of heredity and variation.

GENOTYPE: The fundamental hereditary (genetic) constitution of an organism.

GEOMETRY FACTOR: The fraction of the total solid angle about the source of radiation that is subtended by the face of the sensitive volume of a detector.

GERM CELLS: The cells of an organism whose function it is to reproduce its kind.

GONAD: A gamete-producing organ in animals; testis or ovary.

GRAM ATOMIC WEIGHT: A mass in grams numerically equal to the atomic weight of an element.

GRAM MOLECULAR WEIGHT (GRAM-MOLE): Mass in grams numerically equal to the molecular weight of a substance.

GRAVITATION: Force of attraction existing between all material bodies in the universe. The magnitude of the force between any two bodies is proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them.

GRENZ RAYS: X-rays produced at voltages of 5 to 20 kv.

HALF LIFE, RADIOACTIVE: Time required for a radioactive substance to lose 50% of its activity by decay.

HALF VALUE LAYER (HALF THICKNESS): The thickness of any particular material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value

HARDNESS: A relative specification of the quality or penetrating power of x-rays. In general the shorter the wavelength the harder the radiation.

HEALTH PHYSICS: A term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation.

HEAVY WATER: Popular name for water of which the hydrogen component is deuterium

HEREDITY: Transmission of characters and traits from parent to offspring.

HETEROGENEOUS REACTOR: A nuclear reactor in which the fissionable material and moderator are arranged as discrete bodies (usually according to a regular pattern) of such dimensions that a nonhomogeneous medium is presented to the neutrons. See HOMOGENEOUS REACTOR;

HOLD-BACK CARRIER: The inactive isotope or isotopes of a radioactive element(s), or an element of similar properties, or some reagent which may be used to diminish the amount of the radionuclide coprecipitated or adsorbed in a chemical reaction.

HOMOGENEOUS REACTOR: A nuclear reactor in which the fissionable material and the moderator (if used) are combined in a mixture such that an effectively homogeneous medium is presented to the neutrons. Such a mixture is represented either by a solution of fuel in moderator or by discrete particles having dimensions small in comparison with the neutron mean free path.

IMMUNITY: The power which a living organism possesses to resist and overcome infection.

IMPLANT (Radiology): Radioactive material in a suitable container, to be embedded in a tissue for therapeutic purposes. It may be permanent (seed) or temporary (needle).

INDUCED RADIOACTIVITY: That radioactivity produced in a substance after bombardment with neutrons or other particles.

INHERENT FILTRATION (X-Rays): The filtration introduced by the wall of the x-ray tube and any permanent tube enclosure; to be distinguished from added primary and secondary filters.

INTEGRAL DOSE (VOLUME DOSE): A measure of the total energy absorbed by a patient or any object during exposure to radiation. According to British usage the integral dose of x- or gamma rays is expressed in gram-roentgens.

INTEGRATING CIRCUIT: Electronic circuit which records at any time an average value for the number of events occurring per unit time; or an electrical circuit which records total number of ions collected in a given time.

INTEGRATING DOSE METER: Ionization chamber and measuring system designed for determining total radiation administered during an exposure. In medical radiology the chamber is usually designed to be placed on the patient's skin. A device may be included to terminate the exposure when it has reached a desired value.

INTENSIFYING SCREEN: Sheet of cardboard or other substance coated with fluorescent material, placed in contact with the film in radiography. The x- or gamma rays excite the fluorescent substance and the light thus emitted adds to the radiation effect on the film and produces an image of greater density for a given exposure. Sheets of thin lead may be used for the same purpose in industrial radiography with very high energy radiation. In this case the increased effect is due largely to secondary electrons and x-rays emitted by the lead.

INTENSITY (Radiology): Amount of energy per unit time passing through a unit area perpendicular to the line of propagation at the point in question. Often this term is used incorrectly in the sense of dose rate.

INTERNAL CONVERSION: A mode of radioactive decay in which the gamma rays from excited nuclei cause the ejection of orbital electrons from the atom. The ratio of the number of internal conversion electrons to the number of gamma quanta emitted in the de-excitation of the nucleus is called the "conversion ratio".

INTERNAL RADIATION: Exposure to ionizing radiation when the radiation source is within the body as a result of deposition of radioelements in body tissues.

ION: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

ION EXCHANGE: A chemical process involving the reversible interchange of ions between a solution and a particular solid material such as an ion exchange resin consisting of a matrix of insoluble material interspersed with fixed ions of opposite charge.

IONIZATION: The process or the result of any process by which a neutral atom or molecule acquires either a positive or a negative charge.

IONIZATION CHAMBER: An instrument designed to measure quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

IONIZATION DENSITY: Number of ion pairs per unit volume.

IONIZATION PATH (TRACK): The trail of ion pairs produced by an ionizing particle in its passage through matter.

IONIZATION POTENTIAL: The potential necessary to separate one electron from an atom resulting in the formation of an ion pair.

IONIZING EVENT: Any occurrence of a process in which an ion or group of ions is produced.

IONIZING RADIATION: Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

ION PAIR: Two particles of opposite charge, usually referring to the electron and positive atomic or molecular residue resulting after the interaction of radiation with the orbital electrons of atoms.

IRRADIATION: Exposure to radiation.

ISOBAR: One of two or more different nuclides having the same mass number. Originally called isobares but the name isobars is now generally employed.

ISODOSE CHART: Chart showing the distribution of radiation in a medium by means of lines or surfaces drawn through points receiving equal doses. Isodose charts have been determined for beams of x-rays traversing the body, for radium applicators used for intracavitary or interstitial therapy and for working areas where x-rays or radioactive isotopes are employed.

ISOMER: One of several nuclides having the same number of neutrons and protons but capable of existing, for a measurable time, in different quantum states with different energies and radioactive properties. Commonly, the isomer of higher energy decays to one with lower energy by the process of isomeric transition.

ISOMERIC TRANSITION: The process by which a nuclide decays to an isomeric nuclide (i.e. one of the same mass number and atomic number) of lower quantum energy. Isomeric transitions, often abbreviated I. T., proceed by gamma ray and/or internal conversion electron emission.

ISOTONE: One of several different nuclides having the same number of neutrons in their nuclei.

ISOTOPE: One of several different nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

ISOTOPE DILUTION ANALYSIS. A method of chemical analysis for a component of a mixture based on the addition to the mixture of a known amount of labeled component of known specific activity, followed by isolation of a quantity of the component and measurement of the specific activity of that sample. (See Equations Section in the Handbook).

ISOTOPE EFFECT: The effect of the difference in the mass between isotopes of an element on the rate and/or equilibria of chemical transformations.

ISOTOPE SEPARATION: Process in which a mixture of isotopes of an element is separated into its component isotopes or in which the abundance of isotopes in such a mixture is changed.

ISOTOPIC CARRIER: (See CARRIER).

K-ELECTRON CAPTURE: Electron capture from the K shell by the nucleus of the atom. Also loosely used to designate any orbital electron capture process.

KILOVOLT (kv.): Unit of electrical potential equal to 1,000 volts.

KILOVOLTS PEAK (kvp): The crest value of the potential wave in kilovolts. When only one half of the wave is used, the crest value is to be measured on this half of the wave.

LABELED COMPOUND: A compound consisting, in part, of labeled molecules (See below). By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical, or biological processes.

LABELED MOLECULE: A molecule containing one or more atoms distinguished by non-natural isotopic composition (with radioactive or stable isotopes).

LATENT PERIOD: The period or state of seeming inactivity between the time of exposure of tissue to an injurious agent and the beginning of the response.

LD 50 (Radiation dose): (See MEDIAN LETHAL DOSE).

LEAD EQUIVALENT: The thickness of lead affording the same reduction in radiation dose rate under specific conditions as the material in question.

LEAKAGE (OR DIRECT) RADIATION: The radiation which escapes through the protective shielding of an x-ray tube or teletherapy unit. Diagnostic x-ray tubes should have sufficient shielding to reduce the leakage radiation to 0.1 r per hour at 1 m from the target of the tube under maximum rated x-ray tube potential and current. The shielding incorporated in therapeutic x-ray tubes should limit the leakage radiation to a maximum of 1.0 r per hour at 1 m from the target of the tube under the maximum operating conditions.

LESION: Any hurt, wound, or local degeneration.

LEUKEMIA: A disease in which there is great overproduction of white blood cells, or a relative overproduction of immature white cells, and great enlargement of the spleen The disease is variable, at times running a more chronic course in adults than in children. It is almost always fatal. It can be produced in some animals by long-continued exposure to low intensities of ionizing radiation.

LINEAR ABSORPTION COEFFICIENT: A factor expressing the fraction of a beam of radiation absorbed in unit thickness of material. In the expression $I = I_0e^{-\mu x}$, I_0 is the initial intensity, I the intensity after passage through a thickness of the material, x, μ is the linear absorption coefficient.

LINEAR ACCELERATOR: A device for accelerating particles employing alternate electrodes and gaps arranged in a straight line, so proportioned that when their potentials are varied in the proper amplitude and frequency, particles passing through them receive successive increments of energy.

LINEAR AMPLIFIER: A pulse amplifier in which the output pulse height is proportional to an input pulse height for a given pulse shape up to a point at which the amplifier overloads.

MALIGNANT TUMOR: A tumor capable of metastasizing.

MASS: The material equivalent of energy - different from weight in that it neither increases nor decreases with gravitational force.

MASS ABSORPTION COEFFICIENT: The linear absorption coefficient per cm. divided by the density of the absorber in grams per cu. cm. It is frequently expressed as μ/ρ, where μ is the linear absorption coefficient and ρ the absorber density.

MASS DEFECT: Difference between the mass of the nucleus as a whole and the sum of the component nucleon masses.

MASS NUMBER: The number of nucleons (protons and neutrons) in the nucleus of an atom. Symbol: A

MEAN FREE PATH: Average distance a particle travels between collisions.

MEDIAN LETHAL DOSE (MLD): Dose of radiation required to kill, within a specified period, 50 per cent of the individuals in a large group of animals or organisms.

MESON: Short-lived particle carrying a positive or negative charge or no charge and having a variable mass in multiples of the mass of the electron.

METABOLISM: The sum of all the physical and chemical processes by which living organized substance is produced and maintained and by which energy is made available for the uses of the organism

METASTABLE STATE: An excited state of a nucleus which returns to its ground state by the emission of a gamma ray over a measurable half life.

METASTASIS: The transfer in the body of malignant neoplastic cells from the original or parent site to a more distant one.

MILLIROENTGEN (mr): A submultiple of the roentgen equal to one one thousandth (1/1000th) of a roentgen. (See ROENTGEN).

MODERATOR: Material used in a nuclear reactor to moderate, i.e. slow down, neutrons from the high energies at which they are released.

MOLECULE: Ultimate unit quantity of a compound which can exist by itself and retain all the properties of the original substance.

MOLECULAR WEIGHT: The relative weight of a molecule of any substance as compared to the weight of an atom of oxygen (oxygen has been accepted as the standard and assigned the value of 16.000).

MOMENTUM: The product of the mass of a body and its velocity; cgs units: gm-cm/sec.

MONITORING: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region, as a safety measure for purposes of health protection. Area Monitoring: Routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room or equipment. Usage in some laboratories or operations distinguishes between routine monitoring and survey activities. Personnel Monitoring: Monitoring any part of an individual, his breath, or excretions, or any part of his clothing. (See also RADIOLOGICAL SURVEY).

MONOCHROMATIC RADIATION: Electromagnetic radiation of a single wave length, or in which all the photons have the same energy.

MONOENERGETIC RADIATION: Particulate radiation of a given type (alpha, beta, neutron, etc.) in which all particles have the same energy.

MUTATION: A change in the characteristics of an organism produced by an alteration of the usual hereditary pattern.

N UNIT: That quantity of neutron radiation measured in a Victoreen Condenser r meter that will produce the same amount of ionization as one roentgen of x-radiation.

NEOPLASM: A new growth of cells which is more or less unrestrained and not governed by the usual limitations of normal growth. Benign: If there is some degree of growth restraint and no spread to distant parts. Malignant: If the growth invades the tissues of the host, spreads to distant parts, or both.

NEUTRON: Elementary nuclear particle with a mass approximately the same as that of a hydrogen atom and electrically neutral; its mass is 1.00893 mass units.

NUCLEAR FISSION: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

NUCLEAR FUSION: Act of coalescing two or more atomic nuclei.

NUCLEAR REACTOR: An apparatus in which nuclear fission may be sustained in a self-supporting chain reaction. The usual components of a nuclear reactor are as follows: 1) fissionable material (fuel) such as uranium or plutonium, 2) moderating material (unless it is a fast reactor), 3) usually a reflector to conserve escaping neutrons, 4) provision for heat removal, and 5) measuring and control elements. The terms "pile" and "reactor" have been used interchangeably.

NUCLEAR SYNTHESIS: (Fusion): The fusion of light nuclei to form more complex nuclei with an attendant release of energy resulting from a conversion of matter. An example is the reaction which occurs in the sun whereby helium is synthesized by the fusion of hydrogen atoms with an overall reduction of mass that results in an equivalent release of energy.

NUCLEON: Common name for a constituent particle of the nucleus. At present applied to protons and neutrons, but will include any other particle found to exist in the nucleus.

NUCLEUS (Of a cell): A definitely delineated body within the cell, containing the chromosomes.

NUCLEUS (Of an atom): That part of an atom in which most of the mass and the total positive electric charge are concentrated.

NUCLIDE: A general term referring to any nuclear species of the chemical elements capable of existing for a measurable time.

OPERATING VOLTAGE: As applied to radiation detection instruments; voltage across the electrodes in the detecting chamber required for proper detection of an ionizing event.

ORGAN: Organized group of tissues having one or more definite functions to perform in an animal body.

OSMOSIS: The diffusion which proceeds through a semi-permeable membrane separating two miscible solutions, and tends to equalize their concentrations.

OSMOTIC: Pertaining to osmosis.

PAIR PRODUCTION: An absorption process for x- and gamma radiation in which the incident photon is annihilated in the vicinity of the nucleus of the absorbing atom, with subsequent production of an electron and positron pair. This reaction only occurs for incident photon energies exceeding 1.02 Mev.

PARTICLE ACCELERATOR: (See ACCELERATOR).

PERCENTAGE DEPTH DOSE: Amount of radiation delivered at a specified depth in tissue, expressed as a percentage of the amount delivered at the skin.

PERIODIC TABLE: An arrangement of chemical elements in order of increasing atomic number. Elements of similar properties are placed one under the other, yielding groups and families of elements. Within each group there is a gradation of chemical and physical properties but in general a similarity of chemical behavior. From group to group, however, there is a progressive shift of chemical behavior from one end of the table to the other.

PERMEABLE: Affording passage or penetration.

PERMISSIBLE DOSE: The amount of radiation which may be received by an individual within a specified period with expectation of no harmful result to himself. For long-continued x- or gamma ray exposure of the whole body it is 0.3 r per week measured in air.

PERSONNEL MONITORING: The systematic periodic check of the radiation dose each person receives during his working hours.

PHANTOM: A volume of material approximating as closely as possible the density and effective atomic number of tissue. Ideally a phantom should behave in respect to absorption of radiation in the same manner as tissue. Radiation dose measurements made within or on a phantom provides a means of determining the radiation dose within or on a body under similar exposure conditions. Some of the materials commonly used as phantoms are water, masonite, presdwood, and beeswax.

PHOSPHORESCENCE: Emission of radiation by a substance as a result of previous absorption of radiation of shorter wavelength. In contrast to fluorescence, the emission may continue for a considerable time after cessation of the exciting irradation.

PHOTOELECTRIC EFFECT: A process by which a photon ejects an electron from an atom All the energy of the photon is absorbed in ejecting the electron and in imparting kinetic energy to it.

PHOTOFLUOROGRAPHY: (See FLUOROGRAPHY).

PHOTOGRAPHIC DOSIMETRY: Determination of the cumulative dosage of radiation by use of photographic film.

PHOTOSYNTHESIS: Synthesis with energy from light: specifically, the synthesis of carbohydrates by green plants in the presence of sunlight through the agency of chlorophyll.

PHOTON: A quantity of electromagnetic energy whose value in ergs is the product of its frequency in cycles per sec. and Planck's constant. The equation is: $E = h\nu$.

PILE: (See NUCLEAR REACTOR).

PLANCK'S CONSTANT: A natural constant of proportionality (h) relating the frequency of a quantum of energy to the total energy of the quantum: $h = \frac{E}{\nu} = 6.6 \times 10^{-27}$ erg-sec. (See PHOTON).

PLATEAU: As applied to radiation detector chambers, the level portion of the counting rate-voltage curve where changes in operating voltage introduce minimum changes in the counting rate.

POLYCYTHEMIA: A disease characterized by over-production of red blood cells.

POLYMERIZATION: Union of two or more molecules of a compound to form a more complex molecule.

POSITRON: Particle equal in mass to the electron and having an equal but opposite charge.

POTENTIAL DIFFERENCE: Work required to carry a unit positive charge from one point to another.

PRIMARY PROTECTIVE BARRIERS: Barriers sufficient to reduce the useful beam to the permissible dose rate.

PRIMARY RADIATION: All radiation coming directly from the target of an x-ray tube.

PROMPT GAMMA: Gamma radiation emitted at the time of fission of a nucleus.

PROPORTIONAL COUNTER: Gas filled radiation detection tube in which the pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

PROPORTIONAL REGION: Voltage range in which the gas amplification is greater than one and in which the charge collected is proportional to the charge produced by the initial ionizing event.

PROTECTIVE BARRIERS: Barriers of radiation-absorbing material, such as lead, concrete and plaster, that are used to reduce radiation hazards.

PROTIUM: A name sometimes applied to the hydrogen isotope of mass 1, ($_1H^1$) in contradistinction to deuterium, ($_1H^2$) and tritium ($_1H^3$).

PROTON: Elementary nuclear particle with a positive electric charge equal numerically to the charge of the electron and a mass of 1.007575 mass units.

PULSE HEIGHT SELECTOR: A circuit designed to select and pass voltage pulses in a certain range of amplitudes.

PURPURA: Large hemorrhagic spots in or under the skin or mucous tissues.

QUALITY (Radiology): The characteristic spectral-energy distribution of x-radiation. It is usually expressed in terms of effective wavelengths or half value layers of a suitable material, viz: up to 20 kv (peak), cellophane; 20 to 120 kv (peak) aluminum; 120 to 400 kv (peak),copper; over 400 kv,tin.

QUANTUM: Synonymous with PHOTON.

QUANTUM THEORY: Concept that energy is radiated intermittently in units of definite magnitude called quanta, and absorbed in a like manner.

QUENCHING: The process of inhibiting continuous or multiple discharge in a counter tube which uses gas amplification.

QUENCHING VAPOR: Polyatomic gas used in Geiger-Mueller counters to quench or extinguish avalanche ionization

RABBIT: A small container propelled, usually pneumatically or hydraulically, through a tube in a nuclear reactor for exposing substances experimentally to the radiation and neutron flux of the active section; used for rapid removal of samples with very short half-lives

RAD: The unit of absorbed dose, which is 100 ergs/g. The rad is a measure of the energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It is a unit that was recommended and adopted by the International Commission on Radiological Units at the Seventh International Congress of Radiology Copenhagen, July, 1953.

RADIANT ENERGY: The energy of electro-magnetic waves, such as radio waves, visible light, x-rays and gamma rays.

RADIATION: 1. The emission and propagation of energy through space or through a material medium in the form of waves; for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. 2. The energy propagated through space or through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term radiation, or radiant energy, when unqualified, usually refers to electromagnetic radiation; such radiation commonly is classified, according to frequency, as Hertzian, infrared, visible (light), ultraviolet, x-ray, and gamma ray. (See PHOTON).
3. By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, as cosmic radiation.

RADIATION HYGIENE: Synonymous with RADIOLOGICAL HEALTH.

RADIATION SICKNESS: In radiation therapy: A self-limited syndrome characterized by nausea, vomiting, diarrhea, and psychic depression, following exposure to appreciable doses of ionizing radiation, particularly to the abdominal region. Its mechanism is unknown and there is no satisfactory remedy. It usually comes on a few hours after a treatment and may subside within a day. It may be sufficiently severe to necessitate interrupting the treatment series, or to incapacitate the patient. In atomic bomb disaster: The syndrome associated with intense acute exposure to ionizing radiations is found in the Biological Data Section of the Handbook.

RADIATION THERAPY: Treatment of disease with any type of radiation.

RADIOACTIVE EQUILIBRIUM: Among the members of a radioactive series, the state which prevails when the ratios between the amounts of successive members of the series remain constant. Secular equilibrium: If a parent element has a very much longer half-life than the succeeding ones, so that there is no appreciable change in its amount in the time interval required for the later products to attain equilibrium, then, after the condition is reached, equal numbers of atoms of all members of the series disintegrate in unit time. This condition is never actually attained, but is essentially established in such a case as radium and its series through Radium C. The half-life of radium is 1600 years, of radon, 3.82 days, and of each of the subsequent members, a few minutes. After about a month essentially the equilibrium amount of radon is present, and then for a long time all members of the series disintegrate the same number of atoms per unit time. Transient equilibrium: If the half-life of the parent is sufficiently short, so that the quantity present decreases appreciably during the period under consideration, but is still longer than that of successive members of the series, a stage of equilibrium will be reached, after which all members of the series decrease in amount exponentially with the period of the parent. An example of this is radon, with a half-life of 3.82 days, and the successive members of the series through Radium C.

RADIOACTIVITY: Process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles, beta particles, and gamma photons. The property of radioactivity is exhibited by more than fifty naturally occurring isotopes (natural radionuclides) and is commonly referred to as natural radioactivity. The property of radioactivity can be induced in certain elements under controlled conditions and in such instances the resultant radioactivity is referred to as artificial radioactivity.

RADIOAUTOGRAPH: (See AUTORADIOGRAPH).

RADIOBIOLOGY: That branch of biology which deals with the effects of radiation on biological systems.

RADIOGRAPHY: The making of shadow images on photographic emulsion by the action of ionizing radiation. The image is the result of the differential absorption of the radiation in its passage through the object being radiographed.

RADIOLOGICAL HEALTH: The art and science of protecting human beings from injury by radiation.

RADIOLOGICAL SURVEY: Evaluation of the radiation hazards incident to the production, use, or existence of radioactive materials or other sources of radiation under a specific set of conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

RADIOLOGY: That branch of medicine which deals with the diagnostic and therapeutic applications of radiant energy including x-rays and radioisotopes.

RADIORESISTANCE: Relative resistance of cells, tissues, organs, or organisms to the injurious action of radiation. The term may also be applied to chemical compounds or to any substances. (See also RADIOSENSITIVITY).

RADIOSENSITIVITY: Relative susceptibility of cells, tissues, organs, organisms, or any substances to the injurious action of radiation. Radioresistance and radiosusceptibility are at present employed in a comparative sense, rather than in an absolute one.

RECOMBINATION: The return of an ionized atom or molecule to the neutral state.

RECOVERY (Radiobiology): The return toward normal of a particular cell, tissue, or organism after radiation injury.

RECOVERY RATE: The rate at which recovery takes place following radiation injury. It may proceed at different rates for different tissues. Differential recovery rate: Among tissues recovering at different rates those having slower rates will ultimately suffer greater damage from a series of successive irradiations. This differential effect is taken advantage of in fractionated radiation therapy if the neoplastic tissues have a slower recovery rate than surrounding normal structures.

REGENERATIVE PROCESS: The process by which damaged cells are replaced by new ones of the same type.

RELATIVE BIOLOGICAL EFFECTIVENESS: The ratio of gamma ray or x-ray dose to the dose that is required to produce the same biological effect by the radiation in question

RELATIVE PLATEAU SLOPE: The relative increase in the number of counts as a function of voltage expressed in percentage per 100 volts increase above the Geiger threshold.

RELATIVISTIC MASS: The increased mass associated with a particle when its velocity is increased. The increase in mass becomes appreciable only at velocities approaching the velocity of light, 3 x 10^{10} cm/sec.

RESOLVING TIME, COUNTER: The minimum time interval between two distinct events which will permit both to be counted. It may refer to an electronic circuit, to a mechanical indicating device, or to a counter tube.

RESONANCE CAPTURE: An inelastic nuclear collision occurring when the nucleus exhibits a strong tendency to capture incident particles or photons of particular energies.

RESPIRATION (Biological): The taking in of oxygen and giving off of carbon dioxide, and all steps involved in the process.

RESPIRATORY SYSTEM: The group of organs concerned with the exchange of oxygen and carbon dioxide in organisms. In higher animals this consists successively of the air passages through the mouth, nose, and throat, the trachea, the bronchi, the bronchioles, and the alveoli of the lungs.

ROENTGEN: The quantity of x- or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign.

ROENTGEN EQUIVALENT MAN (REM): That quantity of any type ionizing radiation which when absorbed by man produces an effect equivalent to the absorption by man of one roentgen of x- or gamma-radiation (400 KV).

ROENTGEN EQUIVALENT PHYSICAL (REP): The amount of ionizing radiation which will result in the absorption in tissue of 83 ergs per gram. (Recent authors have suggested the value 93 ergs per gram).

ROENTGENOGRAPHY: Radiography by means of x-rays.

ROENTGENOLOGY: That part of radiology which pertains to x-rays.

ROENTGEN RAYS: X-rays.

ROTATION THERAPY: Radiation therapy during which either the patient is rotated before the source of radiation or the source is revolved around the patient. In this way, a larger dose is built up at the center of rotation within the patient's body than on any area of the skin.

SARCOMA: Malignant neoplasm composed of cells imitating the appearance of the supportive and lymphatic tissues.

SCALER: An electronic device which registers current pulses received over a given time interval.

SCATTERED RADIATION: Radiation which, during its passage through a substance, has been deviated in direction. It may also have been modified by an increase in wavelength. It is one form of secondary radiation.

SCATTERING: Change of direction of sub-atomic particle or photon as a result of a collision or interaction.

SCINTILLATION COUNTER: The combination of phosphor photo-multiplier tube and associated circuits for counting light emissions produced in the phosphors.

SECONDARY PROTECTIVE BARRIERS: Barriers sufficient to reduce the stray radiation to the permissible dose rate.

SECONDARY RADIATION: Radiation originating as the result of absorption of other radiation in matter. It may be either electro-magnetic or particulate in nature.

SELECTIVE LOCALIZATION (Biology): As applied to radioisotopes, accumulation of a particular isotope to a significantly greater degree in certain cells or tissues. (See DIFFERENTIAL ABSORPTION RATIO).

SELF ABSORPTION: Absorption of radiation emitted by radioactive atoms by the matter in which the atoms are located; in particular, the absorption of radiation within a sample being assayed.

SENSITIVE VOLUME: That portion of a counter tube or ionization chamber which responds to a specific radiation.

SIGMOID CURVE: S-shaped curve, often characteristic of a dose-effect curve in radiobiological studies.

SKIN DOSE (Radiology): Dose at center of irradiation field on skin. It is the sum of the air dose and back scatter.

SLUG: A bar-shaped piece of material prepared especially for insertion in a nuclear reactor. The term often refers to the fuel unit of a natural uranium-graphite reactor

SOFTNESS: A relative specification of the quality or penetrating power of x-rays. In general the longer the wavelength the softer the radiation.

SOMATIC CELLS: Body cells, usually having two sets of chromosomes, as opposed to germ cells.

SPALLATION: A term used to denote a nuclear reaction induced by high energy bombardment and involving the "chipping" of fragments off the target nucleus.

SPECIFIC ACTIVITY, ELEMENT: Total radioactivity of a given isotope per gram of element.

SPECIFIC ACTIVITY, ISOTOPE: Total radioactivity of a given isotope per gram of the radioactive isotope.

SPECIFIC ACTIVITY, COMPOUND: Total radioactivity of a given isotope per gram of compound.

SPECIFIC IONIZATION: Number of ion pairs per unit length of path of the ionization particle in a medium, e.g per cm. of air or per micron of tissue.

SPURIOUS COUNT: In a radiation counting device a count caused by any agency other than radiation.

STABLE ISOTOPE: A non-radioactive isotope of an element.

STEM RADIATION: X-rays given off from parts of the anode other than the target; in particular, from the target support

STERILITY (Biological): Temporary or permanent incapability to reproduce.

STOPPING POWER: The reciprocal of the thickness of a solid that absorbs the same amount of alpha radiation as one cm. of air.

STRAY RADIATION: Radiation not serving any useful purpose. It includes direct radiation and secondary radiation from irradiated objects.

SUBCRITICAL: Having an effective multiplication constant less than one so that a self supporting fission chain reaction cannot be maintained.

SYNCHRO-CYCLOTRON: A cyclotron in which the radio frequency of the electric field is frequency-modulated to permit acceleration of particles to relativistic energies.

SYNCHROTRON: A device for accelerating particles, ordinarily electrons, in a circular orbit in an increasing magnetic field applied in synchronism with the orbital motion.

SYNDROME: The complex of symptoms associated with any disease.

TARGET THEORY (HIT THEORY): Theory explaining some biologic effects of radiation on basis of ionization occurring in a very small sensitive region within the cell. One, two, or more "hits", i.e. ionizing events within the sensitive volume may be necessary to bring about the effect.

TAGGED COMPOUND: (See LABELED COMPOUND).

TELETHERAPY: A method of using a radioisotope as a radiation source in which the radioelement is shielded on all sides except one, thus giving a directional beam of radiation which is directed at the area to be treated.

THIMBLE IONIZATION CHAMBER: A small cylindrical or spherical ionization chamber, usually with walls of organic material.

THRESHOLD DOSE: The minimum dose that will produce a detectable degree of any given effect.

TISSUE DOSE: Radiation dose received by a tissue in the region of interest. In the case of x-rays and gamma rays, tissue doses are expressed in roentgens. At the present time the rep is the generally accepted unit of tissue dose for other ionizing radiations.

TISSUE EQUIVALENT IONIZATION CHAMBER: Ionization chamber in which the material of the walls, electrodes, and gas are so selected as to produce ionization essentially equivalent to that characteristic of the tissue under consideration. In some cases it is sufficient to have only tissue equivalent walls, and the gas may be air, provided the air volume is negligibly small. The essential requisite in this case is that the contribution to the ionization in the air made by ionizing particles originating in the air is negligible compared to that produced by ionizing particles characteristic of the wall material.

TISSUE EQUIVALENT MATERIAL: Material made up of the same elements in the same proportions as they occur in some particular biological tissue. In some cases the equivalence may be approximated with sufficient accuracy on the basis of effective atomic number.

TOLERANCE DOSE: Synonym for "permissible dose" The latter is generally considered the preferrable term.

TRACER, ISOTOPIC: The isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

TRACK: Visual manifestation of the path of an ionizing particle in a cloud chamber or nuclear emulsion.

TRANSMUTATION: 1) Any process in which a nuclide is transformed into a different nuclide. 2) More specifically the transformation of a nuclide into a different element by a nuclear reaction.

TRITIUM: ($_1H^3$ or T) The hydrogen isotope having one proton and two neutrons in the nucleus.

TUMOR: In its general sense a swelling. The term is often synonymous with neoplasm.

USEFUL BEAM (In radiology): That part of the primary radiation which passes through the aperture, cone, or other collimator.

VALENCE: Number representing the combining or displacing power of an atom; number of electrons lost, gained, or shared by an atom in a compound; number of hydrogen atoms with which an atom will combine, or which it will displace.

VALENCE ELECTRON: Electron which is gained, lost, or shared in a chemical reaction.

VAN DE GRAAFF GENERATOR: An electrostatic generator which employs a system of conveyor belt and spray points to charge an insulated electrode to a high potential.

VOLUME DOSE: (See INTEGRAL DOSE).

WAVE LENGTH: Distance between any two similar points of two consecutive waves; for electromagnetic radiation the wave length is equal to the velocity of light (c) divided by the frequency of the wave (ν).

WAVE MOTION: The transmission of a periodic motion or vibration through a medium or empty space. Transverse wave motion is that in which the vibration is perpendicular to the direction of propagation. Longitudinal wave motion is that in which the vibration is parallel to the direction of propagation.

X-RAYS: Penetrating electromagnetic radiations having wavelengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and to those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called Roentgen rays after their discoverer, W. C. Roentgen.

SECTION II

Signs and Symbols

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SIGNS AND SYMBOLS

Mathematics

$+$	plus, addition, positive
$-$	minus, subtraction, negative
$\pm$	plus or minus, positive or negative
$\mp$	minus or plus, negative or positive
$\div$, $/$, —	division
$\times$, $\cdot$, () ()	multiplication
() []	collection
$=$	is equal to
$\neq$	is not equal to
$\equiv$	is identical to
$\cong$	equals approximately, congruent
$>$	greater than
$\ngtr$	not greater than
$\geqq$	greater than or equal to
$<$	less than
$\nless$	not less than
$\leqq$	less than or equal to
$::$	proportional to
$:$	ratio
$\sim$	similar to
$\propto$	varies as, proportional to
$\rightarrow$	approaches
∞	infinity
$\therefore$	therefore

$\sqrt{\ }$	square root
$\sqrt[n]{\ }$	nth root
a^n	nth power of a
$\log$, $\log_{10}$	common logarithm
$\ln$, $\log_e$	natural logarithm
e or ϵ	base of natural logs, 2.718
π	pi, 3.1416
$\angle$	angle
$\perp$	perpendicular to
$\parallel$	parallel to
n	any number
$\lvert n \rvert$	absolute value of n
$\bar{n}$	average value of n
a^{-n}	reciprocal of nth power of a $=\left[\frac{1}{a^n}\right]$
n°	n degrees
n'	n minutes, n feet
n''	n seconds, n inches
$f(x)$	function of x
Δx	increment of x
dx	differential of x
Σ	summation of
sin	sine
cos	cosine
tan	tangent

GREEK ALPHABET

Alpha	Α	α	Iota	Ι	ι	Rho	Ρ	ρ
Beta	Β	β	Kappa	Κ	κ	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	Τ	τ
Delta	Δ	δ	Mu	Μ	μ	Upsilon	Υ	υ
Epsilon	Ε	ε	Nu	Ν	ν	Phi	Φ	φ
Zeta	Ζ	ζ	Xi	Ξ	ξ	Chi	Χ	χ
Eta	Η	η	Omicron	Ο	ο	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω

SIGNS AND SYMBOLS
ALPHABETICALLY BY NAME

absolute temperature	T
absorption coefficient, linear	μ
acceleration, linear	a
activity (radio)	A
activity, original	A_o
alpha particle	α
angle, between incident and scattered radiation	θ
Angstrom unit	Å
area	A,S,c
atomic number	Z
Avogadro's number	N, N_o
barn (cross section)	σ
base of natural logarithms	e
beta ray (particle)	$\beta, \beta^-, {}_{-1}\beta^o$
build-up factor	b
capacitance	C
charge electric	Q
curie	c
decay constant	λ
density	d
film (optical)	D
general	d
general or vapor	ρ
deuterium	D
deuteron	d
dielectric constant	ϵ
distance, linear	s,d
electric field intensity	e
electron; beta particle	$e, {}_{-1}e^o$
electronic charge	e, -e
elimination constant, biological	λ_b
energy	E
kinetic	E_k
potential	E_p
Faraday's constant	F
finite increment	Δ
force	F
frequency	
mechanics and electricity	f
wave motion and quantum theory	ν
gamma ray, photon	γ
gas constant	R
gravitational constant	G
half-life, physical	$T_{1/2}$
half-life, biological	T_b
half-life, effective	T_{eff}
intensity of radiation	I
intensity, Radiation, initially	I_o

mass	m
of the electron (rest)	m_e
of the hydrogen atom	m_H
of the neutron	m_n
of the proton	m_p
mass number	A
mean free path	$\bar{l}, \bar{\lambda}$
microcurie	μc
micro-microcurie	μμc
micron	μ
microseconds	μs
millimicrons	mμ
momentum	mv, p
neutron	n, $_0n^1$
number, original	N_0
of counts	n
photon energy	hν
Planck's constant	h
positron	$\beta^+, {}_{+1}\beta^0, {}_{+1}e^0$
positron charge	+e
potential, potential drop	V
pressure	P
proton	p, $_1H^1$
quantum of energy	hν
radius, radial distance	r
range (radiation)	R
rate, count	R
of alpha	R_α
resolving time	τ
roentgen	r
Rutherford	rd
standard deviation, observed	S
theoretical	σ
temperature	t
absolute (Kelvin)	°K, T
absolute (Rankine)	°R
centigrade	t_c
fahrenheit	t_f
time	t
increment	φ
triton	t
universal gas constant	R
velocity	
light in vacuum	c
linear or particle	v
volume	V
wave	
frequency	ν
length	λ
weight	wt.
work function	φ
work	W

SIGNS AND SYMBOLS
ALPHABETICALLY BY SYMBOL

A	activity (radio); area; atomic mass number
Å	Angstrom unit
A_o	activity, original
a	acceleration, linear
b	build-up factor
C	capacitance, concentration μc/gm.
c	curie; velocity of light in vacuum
D	density, film; deuterium; dose, dosage
d	density, general; deuteron; distance, linear
E	energy
E_k	energy, kinetic
E_p	energy, potential
e	base of natural logarithms; electric field intensity
e,-e	charge of the electron
$_{-1}e^o$	electron; beta particle
$_{+1}e^o$	positron
+e	charge of the positron
F	Faraday's constant; force
f	frequency
G	gravitational constant
$_1H^1$	proton
h	Planck's constant
hν	photon energy; quantum
I	intensity of radiation
I_o	initial intensity; exposure
°K	degrees Kelvin; absolute temperature
l	length
$\bar{l}$	mean free path
m	mass
m_e	rest mass of electron
m_H	mass of the hydrogen atom
m_n	mass of the neutron
m_p	mass of the proton
mc	millicurie
mμ	millimicron
mu	mass unit
mv	momentum
N	Avogadro's number; number
N_o	Avogadro's number; number of radioactive atoms at zero time; number, original
n	neutron; number, any; number, original
$_on^1$	neutron
p	momentum; pressure; proton
Q	electric charge; reaction energy in Mev
R	range, (radiation); rate, count; resistance; universal gas constant
°R	absolute temperature; degrees Rankine

$R\alpha$	range of α
r	radius; radial distance; roentgen
rd	Rutherford
S	area; observed standard deviation
s	distance, linear
$T_{1/2}$	half-life, physical
T_b	half-life, biological
T_{eff}	half-life, effective
T	temperature, absolute
t	temperature, general; time; triton
t_c	temperature, °centigrade
t_f	temperature, °fahrenheit
V	volume; potential; potential drop, volt
v	velocity, linear or particle
W	work
wt.	weight
x	absorber thickness
Z	atomic number
α	alpha particle
$\beta, \beta^-, {}_{-1}\beta^o$	beta ray (particle)
$\beta^+, {}_{+1}\beta^o$	positron
γ	gamma ray
Δ	finite increment
ϵ	dielectric constant
θ	angle between incident & scattered radiation
κ	pair production coefficient

λ	decay constant; wave length
$\bar{\lambda}$	mean free path
λ_b	biological elimination constant
μ	absorption coefficient; effective or apparent, linear; micron, micro
μ_a	$\tau + \kappa + \sigma_a$ = energy absorption coefficient for air
μ_o	total absorption coefficient
μc	microcurie
$\mu\mu$	micromicrons
$\mu\mu c$	micro-microcurie
μs	microseconds
ν	frequency (wave motion quantum theory)
ρ	density, general or vapor
σ	area; barn (cross section); theoretical standard deviation; Compton collision coefficient
σ_a	absorption cross sections in barns; Compton absorption coefficient
σ_{ac}	activation cross section in barns
σ_{eff}	effective cross section in barns
σ_s	Compton scatter coefficient; scattering cross section in barns
σ_t	total cross section in barns
τ	resolving time; photoelectric coefficient
ϕ	work function; time increment

ABBREVIATIONS

abs	absolute
a.c.	alternating current
alk	alkali
amal	amalgam; amalgamated
amp	ampere
amu	atomic mass unit
antilog	antilogarithm
appr.	approximately
aq.	aqua; aqueous; water
asym.	asymmetrical
atm. or atmos.	atmosphere (atmospheric)
at. no.	atomic number
at. wt.	atomic weight
aux	auxiliary
av.	average
bar	barometer
Bev.	billion electron volts
BTU	British thermal unit
C	centigrade
cal.	calorie (gram)
cc or c.c.	cubic centimeter
c. cm	cubic centimeter
cf.	confer, compare
c.f.m.	cubic foot per minute
cgs	centimeter-gram-second system of units
chem.	chemical, chemistry
cir.	circular
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
coef.	coefficient
colog.	cologarithm
conc.	concentrated
const.	constant
cu.	cubic
cu.cm.	cubic centimeter
cu.ft.	cubic foot
cu.in.	cubic inch
cu.m.	cubic meter
cu.yd.	cubic yard
cwt.	hundredweight
cyl.	cylinder
d	day, deuteron, density
D	deuterium, density
d.c.	direct current
def.	definition(s)
deg.	degree, (thermometric) generally absolute C.
dens.	density
D.F.	decontamination factor
diam.	diameter
dil.	dilute
dis.	disintegrations

EC	orbital electron capture
emu	electromagnetic unit of charge
equiv.	equivalent
es	electrostatic or cgs. unit of quantity of electricity
ev	electron volt
exp.	exponential function
F	fahrenheit
fahr.	fahrenheit
F.S.	factor of safety
ft.	foot
ft.^{2}	square foot
ft.^{3}	cubic foot
ft.-lb.	foot-pound
g	gram
G.A.W.	gram atomic weight
g-cal. or g.-cal.	gram calorie
gms.	grams
G.M.W.	gram molecular weight
h	hot, hour
hr.	hour
in.	inch
in.^{2}	square inch
in.^{3}	cubic inch
insol.	insoluble
IT	isomeric transition
K	electron capture from K shell, kilo-
Kev.	thousand electron volts
kg	kilogram
kg-cal.	kilogram-calorie
kilo-	prefix meaning 1,000
kva.	kilovolt-ampere
kw	kilowatt
kw.-hr	kilowatt-hour
l	liter
lb.	pound
lin.	linear
liq.	liquid
ln	natural logarithm
log or log.	logarithm
$\log_e$	logarithm to the base e; natural, hyperbolic or Napierian logarithm
$\log_{10}$	common logarithm; logarithm to the base 10
m	meter, milli-
m^2	square meter
m^3	cubic meter
m.	minute
max.	maximum
mb	millibarns
med.	medium
Mev.	million electron volts
mg	milligram
micro-	prefix meaning 1/1,000,000 or 10^{-6}

micro-micro	prefix meaning 10^{-12}
milli-	prefix meaning 1/1,000
milli-micro	prefix meaning 10^{-9}
min.	minute
min.	minim; minimum; mineral
ml	milliliter
mm	millimeter
mm^2	square millimeter
mm^3	cubic millimeter
mol.	molecule
mol.wt.	molecular weight
m u	mass unit
mμ	millimicron; millimicro-
N	numeric; number (in mathematical tables)
Obs.	observer
p.f.	power factor
precip. or p'p't'd	precipitated
Q	quantity
R.F.	reliability factor
r.p.m.	revolutions per minute
s	second; soluble
sol.	solution; soluble
soln.	solution
sp.	specific
SpA	specific activity
sp.gr.	specific gravity
sq.	square
sq.ft.	square foot
sq.in.	square inch
sq.yd.	square yard
std.	standard
sym.	symmetrical
t	triton
th.	thermal
tn.	ton
vel or veloc.	velocity
vert.	vertical
visc	viscous
vol.	volume
wt.	weight
yd.	yard
yr.	year
μ	micron; micro-
μμ	micromicron; micromicro-
μs	microseconds

FUNDAMENTAL CONSTANTS

NAME		VALUE
Avogadro's Number	N_o =	6.025×10^{23} molecules/gm mole
Base of Natural Logarithms	e =	2.7183...
Curie	c =	3.7×10^{10} dis/sec
Electron Charge	e =	4.8×10^{-10} statcoulombs = 1.6×10^{-19} coulombs
Energy Equivalent of Electron Mass	mc^2 =	0.51 Mev
Faraday's Constant	F =	96,522 coulombs/gm equivalent (physical scale)
Frequency Associated With 1 ev	ν_o =	2.4186×10^{14} sec^{-1}
Gravitational Acceleration	g =	980.665 cm/sec^2
Mass. Alpha Particle	m_α =	6.64×10^{-24} gms = 4.002777 mu
Mass, Electron	m_e =	9.1066×10^{-28} gms = 0.000548
Mass, H-Atom	m_H =	1.67339×10^{-24} gms = 1.008142 mu
Mass, Neutron	m_n =	1.6751×10^{-24} gms = 1.008982 mu
Mass, Proton	m_p =	1.67248×10^{-24} gms = 1.007594 mu
Mass Unit	mu =	1.66035×10^{-24} gms = 1.0000 mu
Microcurie	μc =	10^{-6} curies = 3.7×10^4 dis/sec
Micro-microcurie	μμc =	10^{-12} curies = 3.7×10^{-2} dis/sec
Millicurie	mc =	10^{-3} curies = 3.7×10^7 dis/sec
Planck's Constant	h =	6.624×10^{-27} erg-sec
Pi	π =	3.1416...
Roentgen	r =	1 esu/0.001293 gms of air
Rutherford	rd =	10^6 dis/sec
Universal Gas Constant	R =	0.08206 liter-atm/gm-mole/°K
Velocity of Light	c =	2.99776×10^{10} cm/sec
Wave-Length Associated With 1 ev	λ_o =	12394.8 Angstroms

FUNDAMENTAL CONVERSION FACTORS

LENGTH

Length	m	cm	mm	Å
1 meter (m)	1	10^{2}	10^{3}	10^{10}
1 centimeter (cm)	10^{-2}	1	10	10^{8}
1 millimeter (mm)	10^{-3}	10^{-1}	1	10^{7}
1 micron (μ)	10^{-6}	10^{-4}	10^{-3}	10^{4}
1 micromicron (μμ)	10^{-12}	10^{-10}	10^{-9}	10^{-2}
1 Angstrom unit (Å)	10^{-10}	10^{-8}	10^{-7}	1

MASS ENERGY

Mass Energy	Mass Unit	Mev	Ergs	Calories
Mass Unit (mu)	1	931	1.49×10^{-3}	3.56×10^{-11}
Mev	1.07×10^{-3}	1	1.60×10^{-6}	3.83×10^{-14}
Ergs	671	6.24×10^{5}	1	2.39×10^{-8}
Calories	2.81×10^{10}	2.62×10^{13}	4.18×10^{7}	1

TIME

Time	Year	Day	Hour	Minute	Second
1 year	1	365.26	8.766×10^{3}	5.260×10^{5}	3.156×10^{7}
1 day	2.738×10^{-3}	1	24	1.440×10^{3}	8.640×10^{4}
1 hour	1.141×10^{-4}	0.04167	1	60	3.600×10^{3}
1 minute	1.901×10^{-6}	6.944×10^{-4}	0.01667	1	60
1 second	3.169×10^{-8}	1.157×10^{-5}	2.778×10^{-4}	.01667	1

ADDITIONAL CONVERSION FACTORS

Multiply	By	To Obtain
atmospheres	14.70	lbs/sq in
"	76.0	cm Hg
barns	10^{-24}	cm^2
British thermal units	1.055×10^3	joules
" " "	0.2520	kg-cal
Btu/lb	0.556	gm-cal/gram
centimeters	0.3937	inches
"	3.28×10^{-2}	feet
cm Hg	0.1934	lbs/sq in
"	1.316×10^{-2}	atm
"	0.4461	ft of water
cm/sec	0.60	meters/min
"	2.237×10^{-2}	mph
coulombs	2.997×10^9	statcoulombs
cm^3	6.102×10^{-2}	cu in
"	3.531×10^{-5}	cu ft
"	2.642×10^{-4}	gallons
"	10^{-3}	liters
cm^3/sec	2.119×10^{-3}	cu ft/min
"	8.64×10^{-2}	cu meters/day
"	1.585×10^{-2}	gal/min
"	3.6	liters/hour
cm^3/gm	1.602×10^{-2}	cu ft/lb
chemical scale	1.000272	physical scale
cubic feet	2.832×10^{-2}	cubic meters
" "	7.481	gals
" "	28.32	liters
cu ft/lb	62.43	cm^3/gm
cu ft/min	4.72×10^2	cm^3/sec
cu ft/sec	4.488×10^2	gal/min
cu in	16.39	cm^3
" "	5.787×10^{-4}	cu ft
" "	1.639×10^{-2}	liters

ADDITIONAL CONVERSION FACTORS (Continued)

Multiply	By	To Obtain
cu in	4.329×10^{-3}	gals
cubic meters	35.31	cu ft
" "	2.642×10^{2}	gals
cu meters/day	11.57	cm^3/sec
curie	2.22×10^{12}	disintegrations/min
"	3.7×10^{10}	dis/sec
"	10^{3}	millicuries
"	10^{6}	microcuries
"	10^{-3}	kilocuries
disintegrations/min	4.55×10^{-10}	millicuries
" "	4.55×10^{-7}	microcuries
dis/sec	2.7×10^{-8}	millicuries
" "	2.7×10^{-5}	microcuries
dynes	1.02×10^{-3}	gms
"	2.248×10^{-6}	lbs
electron volt (ev)	10^{-6}	Mev
" "	1.6×10^{-12}	ergs
" "	1.6×10^{-19}	joules
ergs	10^{-7}	joules
"	6.24×10^{5}	Mev
"	6.24×10^{11}	ev
feet	30.48	cm
"	0.3048	meters
feet of water	2.242	cm Hg
ft/min	0.508	cm/sec
"	1.667×10^{-2}	ft/sec
"	1.136×10^{-2}	mph
ft/sec	18.29	meters/min
"	0.6818	mph
ft-lbs	1.356	joules
"	3.239×10^{-4}	kg-cal
gals(US)	231	cu in
"	0.1337	cu ft

ADDITIONAL CONVERSION FACTORS (Continued)

Multiply	By	To Obtain
gals (US)	3.785×10^{3}	cm^{3}
"	3.785	liters
"	0.83	gals (Imperial)
gal/min	2.228×10^{-3}	cu ft/sec
grams	980.7	dynes
"	2.205×10^{-3}	lbs
gm-cal	3.968×10^{-3}	Btu
gm-cal/gm	1.8	Btu/lb
gm mole gas	22.4	liters (s.c.)*
gm/cm^{3}	62.43	lbs/cu ft
horsepower	10.7	kg-cal/min
"	0.7457	kw
inches	2.54	cm
in Hg	0.4912	lbs/sq in
joules	10^{7}	ergs
"	0.7376	ft lbs
"	9.486×10^{-4}	Btu
kilocurie	10^{3}	curies
kilogram	9.807×10^{5}	dynes
"	2.205	lbs
kg-cal	3.968	Btu
"	3.068×10^{3}	ft lb
kg-cal/min	9.35×10^{-2}	hp
kilowatt	14.34	kg-cal/min
"	1.341	hp
kw-hr	2.247×10^{19}	Mev
"	3.6×10^{13}	ergs
liters	3.53×10^{-2}	cu ft
"	61.02	cu in
"	0.2642	gal (US)
"	10^{3}	cm^{3}
liters/hr	0.278	cm^{3}/sec
liters/min	15.851	gal/hr

ADDITIONAL CONVERSION FACTORS (Continued)

Multiply	By	To Obtain
meters	3.281	ft
"	39.37	in
meters/min	1.667	cm/sec
" "	5.468×10^{-2}	ft/sec
" "	3.728×10^{-2}	mph
microcuries	3.7×10^{4}	dis/sec
"	2.22×10^{6}	dis/min
miles	5280	feet
mph	44.7	cm/sec
"	88	ft/min
"	1.467	ft/sec
"	26.82	meters/min
millicuries	3.7×10^{7}	dis/sec
"	2.22×10^{9}	dis/min
Mev	1.6×10^{-6}	ergs
ounces	28.35	gms
"	6.25×10^{-2}	lbs
physical scale	.999728	chemical scale
pounds	4.448×10^{5}	dynes
"	453.6	gms
lbs/cu ft	1.602×10^{-2}	gms/cm^3
lbs/cu in	27.68	gms/cm^3
lbs/gal	0.1198	gm/cm^3
lbs/sq in	6.804×10^{-2}	atm
" "	2.036	in Hg
" "	5.17	cm Hg
radians	57.3	degrees
roentgen	1	esu/cm^3 (air, s.c.)*
"	2.083×10^{9}	ion prs/cm^3 (air, s.c.)*
"	1.61×10^{12}	ion prs/gm (air)
"	6.77×10^{4}	Mev/cm^3 (air, s.c.)*
"	5.24×10^{7}	Mev/gm (air)
"	83.8	ergs/gm (air)

ADDITIONAL CONVERSION FACTORS (Continued)

Multiply	By	To Obtain
roentgen	2.0×10^{-6}	cal/gm. (air)
rutherford	10^{6}	dis/sec
square cm	1.076×10^{-3}	sq ft
" "	0.155	sq in
" "	10^{24}	barns
square ft	929	sq cm
" "	144	sq in
" "	9.29×10^{-2}	sq meters
square in	6.452	cm^2
" "	6.944×10^{-3}	sq ft
" "	6.452×10^{-4}	sq meters
square meters	10.76	sq ft
statcoulomb	3.34×10^{-10}	coulombs
temperature deg C + 273	1.0	abs deg Kelvin
temperature deg C	1.8	temp deg F -32
temp deg F + 459	1.0	abs deg Rankine
temp deg F-32	0.5555	temp deg C.
watts	10^{7}	ergs/sec
"	0.7376	ft-lb/sec

* Standard conditions -- 0 deg C (32 deg F.) and 760 mm Hg.

EQUATIONS

A. LOGARITHMIC RELATIONS

log N = the exponent or power to which the base 10 must be raised to obtain a value N. (the common logarithm of N).

ln N = the power to which the base 2.718...(e) must be raised to obtain a value N. (the natural logarithm of N).

(1) $\log N = 0.4343 \ln N$

(2) $\ln N = 2.3026 \log N$

(3) $\log MN = \log M + \log N$

(4) $\log M/N = \log M - \log N$

(5) $\log N^a = a \log N$

(6) $\log \sqrt[a]{N} = (\log N)/a$

B. CLASSICAL PHYSICS

Unless otherwise noted, the symbols and dimensions in this section are used consistently as follows:

m = mass (gm)

v = velocity (cm/sec)

a = acceleration (cm/sec^2)

F = force (gm-cm/sec^2, dynes)

r = radius of action (cm)

s = distance (cm)

(1) Linear Force

$$F = m\,a = (\text{gm})(\text{cm}/\text{sec}^2) = \text{gm-cm}/\text{sec}^2 = \text{dynes}$$

(2) Momentum

$$mv = (\text{gm})(\text{cm}/\text{sec})$$

(3) Conservation of Momentum (any impact between Body A and Body B)

$$m_A v_{Ai} + m_B v_{Bi} = m_A v_{Af} + m_B v_{Bf}$$

i = initial
f = final

(4) Work

$$W = F\,s = m\,a\,s = (\text{gm})(\text{cm}/\text{sec}^2)(\text{cm}) = \text{gm-cm}^2/\text{sec}^2 = \text{dyne-cm} = \text{erg}$$

(5) Energy

$$E = (\text{work}) = F\,s = (\text{gm-cm}/\text{sec}^2)(\text{cm}) = \text{gm-cm}^2/\text{sec}^2 = \text{erg}$$

(6) Kinetic Energy

$$E_k = \tfrac{1}{2}\,m\,v^2 = (\text{gm})(\text{cm}/\text{sec})^2 = \text{gm-cm}^2/\text{sec}^2 = \text{erg}$$

(7) Conservation of Kinetic Energy (elastic impact: Body A and Body B)

$$\tfrac{1}{2}m_A v_{Ai}^2 + \tfrac{1}{2}m_B v_{Bi}^2 = \tfrac{1}{2}m_A v_{Af}^2 + \tfrac{1}{2}m_B v_{Bf}^2$$

(8) Power

$$P = (\text{work/time}) = F\,s/t = (\text{gm-cm/sec}^2)(\text{cm})/\text{sec} = \text{ergs/sec}$$

C. WAVE AND QUANTUM RELATIONS

Unless otherwise noted, symbols and dimensions in this section are used consistently as follows:

v = velocity of wave or particle (cm/sec)
h = Planck's Constant (6.6×10^{-27} erg-sec)
ν = frequency of wave or quanta (cycles/sec)
λ = wave length (cm)
λ_o = wave length of incident radiation (angstroms)
λ_θ = wave length of scattered radiation at angle θ (Angstroms)
E = energy (ergs)
θ = angle between incident and scattered radiation
c = velocity of light (3×10^{10} cm/sec)
m = mass of particle (gm)
ϕ = work function (ergs)

(1) Wave Equation

Wave velocity (v or c) = $\lambda\nu$

(2) Associated Wave Length of a Particle

Wave Length = $\lambda = \dfrac{h}{mv}$

(3) Photoelectric Equation

$$E = \phi + \tfrac{1}{2}mv^2$$

(4) Photon Energy

$$E = h\nu$$

$$E = \frac{hc}{\lambda}$$

$$\text{Energy in electron volts} = \frac{1.242 \times 10^4}{\text{Wave length in Angstroms}}$$

(5) Mass-Energy Relation

$$E = mc^2$$

(6) Momentum of Photon

$$mv = \frac{h}{\lambda}$$

(7) Compton Scattering of Gamma and X-rays

$$\lambda_\theta = \lambda_o + 0.0242\ (1 - \cos\ \theta)$$

D. ELECTROSTATICS

The following units apply in this section:

F = force (dynes)
Q = electrostatic charge (statcoulombs)
s = distance (cm)
V = potential (statvolts)
C = capacitance (statfarads)
W = work (ergs)
ϵ = dielectric constant

(1) Force Between Two Charges, a and b

$$F = \frac{Q_a Q_b}{\epsilon s^2}$$

(2) Work

$$W = Q\ V$$

(3) Capacitance

$$C = Q/V$$

(4) Potential

$$V = Q/s$$

E. RADIOACTIVE DECAY

The following symbols will be used in this section:

N_o = number of unstable nuclei at some original time
N = number of unstable nuclei remaining after a time interval, t.
I_o = intensity of radiation at some original time
I = intensity of radiation after a time interval, t.
A_o = activity of sample at some original time
A = activity remaining after a time interval, t.

λ = decay constant for particular radioactive element
e = base of natural logarithms; 2.718...
t = elapsed time
$T_{\frac{1}{2}}$ = half-life
$n = t/T_{\frac{1}{2}}$ = number of half-lives

(1) $N = N_o e^{-\lambda t}$ or $N = N_o e^{-.693t/T_{\frac{1}{2}}}$

(2) $A = A_o e^{-\lambda t}$ or $A = A_o e^{-.693t/T_{\frac{1}{2}}}$

(3) $I = I_o e^{-\lambda t}$ or $I = I_o e^{-.693t/T_{\frac{1}{2}}}$

(4) $N = N_o 2^{-n}$ or $N/N_o = 1/2^n$

Decay Constant

(5) $\lambda = 0.693/T_{\frac{1}{2}}$

Fission Product Decay

(6) $I_1 t_1^{1.2} = I_2 t_2^{1.2}$

Where I_1 = Radiation intensity at time t_1 after fission
I_2 = Radiation intensity at time t_2 after fission

(7) $A = k_1 t^{-0.89}$ where fission product age is 1 min. $\leq t <$ 30 min.

(8) $A = k_2 t^{-1.11}$ where fission product age is 30 min. $\leq t <$ 1 day.

(9) $A = k_3 t^{-1.25}$ where fission product age is 1 day $\leq t <$ 4 days.

(10) $A = k_4 t^{-1.03}$ where fission product age is 4 days $\leq t <$ 100 days.

(11) $A = k_5 t^{-1.60}$ where fission product age is 100 days $\leq t <$ 3 years.

$k_2 = 2.036\ k_1$
$k_3 = 5.571\ k_1$
$k_4 = 0.857\ k_1$
$k_5 = 771.4\ k_1$

The value of k_1, k_2, k_3, k_4, or k_5, will depend upon the number of atoms fissioned, hence for the general condition these constants cannot have assigned values. The ratios between k_1, and k_2, k_3, k_4, and k_5, will remain the same.

F. SPECIFIC ACTIVITY (Isotopic)

Specific Activity = $\lambda N = 0.693N/T_{\frac{1}{2}}$ = dis/sec/gm

where $T_{\frac{1}{2}}$ = half-life (seconds)

N = number of atoms per gram

Specific Activity = $\lambda N/(3.7 \times 10^{10}) = \dfrac{N \times 1.873 \times 10^{-11}}{T_{\frac{1}{2}}}$ = curies/gm

G. RADIATION ABSORPTION

(1) Alpha Particle Range

$R_\alpha = 0.318 E^{3/2}$ where R_α = range in cm of air at 1 atm and 15°C.

E = energy, Mev.

(2) Beta Particle Range

For $0.01 \leq E \leq 2.5$ Mev

$R = 412\, E^{1.265 - 0.0954 \ln E}$ where R = range in mg/cm^2

$\ln E = 6.63 - 3.2376 [\, 10.2146 - \ln R\,]^{\frac{1}{2}}$ E = max. energy, Mev.

For $E \geq 2.5$ Mev

$R = 530\, E - 106$ where R, E same as above

Sargent's Rule ($E > 0.8$ Mev)

$R = 0.526\, E - 0.094$ where R = range, gm/cm^2

E = max. energy, Mev.

Feather's Rule ($E > 0.6$ Mev)

$R = 0.542\, E - 0.133$ where R, E same as for Sargent's Rule

(3) Gamma Ray Absorption

The following symbols will be used in this section:

I_o = original radiation exposure rate

I = attenuated radiation exposure rate

μ = linear absorption coefficient (cm^{-1}) = $\dfrac{.693}{x_{\frac{1}{2}}}$

μ/ρ = mass absorption coefficient (cm^2/gm)

ρ = absorber density (gm/cm^3)

x = absorber thickness (cm)

$x_{\frac{1}{2}}$ = half value layer of absorber (cm)

e = base of natural logarithms (2.718...)

b = "build-up" factor (See section IV of Handbook for values)

For monoenergetic or monochromatic narrow beam radiation.

$$I = I_o e^{-\mu x} \quad \text{or} \quad I = I_o e^{-(\mu/\rho)(\rho)(x)}$$

For monoenergetic or monochromatic wide beam radiation.

$$I = bI_o e^{-\mu x}$$

(4) Neutron Absorption (for a collimated beam of monoenergetic Neutrons)

$$I = I_o e^{-\sigma N x}$$

where I_o = initial neutron intensities

I = final neutron intensities

N = number of atoms per cc in the absorber

σ = cross section (square centimeters)

x = thickness of absorber (cm)

e = base of the natural logarithm (2.718...)

Since this equation is only an approximation of neutron attenuation, average neutron energies can be used for determining the value of σ. The equation is not accurate enough to justify the use of neutron build-up factors.

H. BETA PARTICLE COUNTING

(1) Self Absorption

$$\frac{R}{R_o} = \frac{1}{mx}\left(1 - e^{-mx}\right)$$

where R = measured counting rate

R_o = true counting rate

x = sample thickness (mg/cm^2)

m = absorption coefficient (cm^2/mg)
(See N.B.S. Handbook 51, p.26)

(2) Resolving Time Determination

$$\tau = \frac{R_1 + R_2 - R_{12}}{2\,(R_1 R_2)}$$

where τ = resolving time, seconds

R_1 = counting rate, source 1 (c/s)
R_2 = counting rate, source 2 (c/s)
R_{12} = counting rate, combined sources 1 and 2 (c/s)

(3) Resolving Time Correction

$$R = \frac{R_o}{1 - R_o \tau}$$

where R = true counting rate (c/s)
R_o = observed counting rate (c/s)
τ = resolving time, seconds

I. STATISTICS OF COUNTING

n = number of counts, one observation
t = counting time, one observation
$\bar{n}$ = mean number of counts, series of observations
$\bar{t}$ = mean counting time, series of observations
m = number of observations
σ = theoretical standard deviation
S_t = observed standard deviation of the time required to record a preset number of counts.
S_n = observed mean standard deviation of the number of counts recorded in a preset time.

a. Theoretical Standard Deviation

$$\sigma_n = \sqrt{\frac{\bar{n}}{m}}$$

b. Observed Standard Deviation

(1) Series of observations, preset time

$$S_n = [\,\Sigma_m (n_m - \bar{n})^2 / m(m-1)]^{\frac{1}{2}}$$

(2) Series of observations, preset count.

$$S_n = (^{n}/\bar{t})\ S_t$$

$$S_t = [\,\Sigma_m (t_m - \bar{t})^2 / m]^{\frac{1}{2}}$$

(3) Reliability Factor

$$R.F. = \frac{S_n}{\sigma_n}$$

J. CALIBRATION PROCEDURES

Gamma Emitter Dose in Air

(1) $I_\gamma = 0.156\, n\, E\, (10^5\, \mu_a)$

where I_γ = mr/hr at 1 meter per mc
n = gamma quanta per disintegration
E = energy of gamma quanta in Mev
μ_a = energy absorption coefficient for gamma in air

(2) Exposure Rate (from point source of radium gamma radiation)

$$\text{mr/hr} = \frac{\text{No. of mg of Ra}}{s^2}$$

where s = distance to source (yd)

$$\text{mr/hr} = \frac{8400\ (\text{no. of mg of Ra})}{s^2}$$

s = distance (cm)

(3) Exposure Rate, Approximate (from any gamma source)

r/hr at 1 foot = 6 C E

where C = number of curies
E = gamma ray energy (Mev)

(4) Exposure Rate (from any gamma source)

$$\text{mr/hr} = nI_\gamma / s^2$$

where n = number of millicuries
I_γ = mr/hr at 1 meter per mc
s = distance (meters)

K. INTERNAL RADIATION DOSAGE

(1) Biological Half-Life

$$T_b = \frac{0.693}{\lambda_b}$$

where λ_b = biological rate of elimination constant
T_b = biological half-life

(2) Effective Half-Life

$$T_{eff} = \frac{(T_{\frac{1}{2}})\,(T_b)}{T_{\frac{1}{2}} + T_b}$$

where T_{eff} = effective half-life
$T_{\frac{1}{2}}$ = radioactive (physical) half-life
T_b = biological half-life

(3) Beta Emitter Dose

$D = 88\ E\ T_{eff}\ C\,(1 - e^{-\lambda_{eff}\,t})$ where D = dose (reps)

E = average energy of beta particle (Mev)

C = μc/gm of radioisotope in tissue

λ_{eff} = effective decay constant (days $^{-1}$)

t = time (days)

L. DECONTAMINATION FACTOR

$$D.F. = \frac{\text{Initial Activity}}{\text{Final Activity}}$$

M. ISOTOPIC DILUTION

a. Single Addition Method

$$w = w' \left(\frac{Sp\,A'}{Sp\,A} - 1\right)$$

where

w = total weight of diluent material (weight of stable material)

w' = total weight of labeled material (weight of radioactive material)

$Sp\,A'$ = specific activity of labeled material

$Sp\,A$ = specific activity of mixture

b. Double Dilution

(1) $$S_o = \frac{S_1\,S_2\,(G_1 - G_2)}{S_2\,G_2 - S_1\,G_1}$$

(2) $$Z = \frac{S_2\,G_2 - S_1\,G_1}{S_1 - S_2}$$

S_o = initial specific activity

S_1 = specific activity of first dilution

S_2 = specific activity of second dilution

G_1 = weight of carrier added for first dilution

G_2 = weight of carrier added for second dilution

Z = weight of original radioactive material

N. NEUTRON ACTIVATION METHODS

$$A_\phi = k\sigma_{ac} fn (1 - e^{-\lambda t}) e^{-\lambda\phi}$$

where A_ϕ = measured activity in net counts per second at time ϕ.

k = efficiency of the counter for measuring the induced radioactivity.

σ_{ac} = cross section for neutron capture by the target material, activation cross section, square centimeters per atom.

f = flux of neutrons (neutrons per square centimeter per second).

n = number target nuclei per square centimeter

λ = disintegration constant of radioactive material

t = time duration of exposure to neutron flux

ϕ = time increment between end of irradiation and the time at which the target is counted.

e = base of natural logarithm (2.718...)

O. GEOMETRY OF A COUNTER

(1) Point Source

$G = 0.5\ (1 - \cos\alpha)$ Where $\alpha = \tan^{-1} \frac{r}{d}$

r = radius of counter window or phosphor

d = distance between counter and source

G = geometry factor

NATURAL (NAPIERIAN) LOGARITHMS

The natural logarithm of a number is the index of the power to which the base e (2.7182818) must be raised in order to equal the number.

Example: $\log_e 4.12 = \ln 4.12 = 1.4159$.

The table gives the natural logarithms of numbers from 1.00 to 9.99 directly, and permits finding logarithms of numbers outside that range by the addition or subtraction of the natural logarithms of powers of 10.

Example: $\ln 679. = \ln 6.79 + \ln 10^2 = 1.9155 + 4.6052 = 6.5207$
$\ln 0.0679 = \ln 6.79 - \ln 10^2 = 1.9155 - 4.6052 = -2.6897$

Natural Logarithms of 10^k

$\ln 10 = 2.302585$
$\ln 10^2 = 4.605170$
$\ln 10^3 = 6.907755$
$\ln 10^4 = 9.210340$
$\ln 10^5 = 11.512925$
$\ln 10^6 = 13.815511$
$\ln 10^7 = 16.118096$
$\ln 10^8 = 18.420681$
$\ln 10^9 = 20.723266$

To obtain the common logarithm, the natural logarithm is multiplied by $\log_{10} e$, which is 0.434294, or $\log_{10} N = 0.434294 \ln N$.

N	0	1	2	3	4	5	6	7	8	9
1.0	**0.0000**	**0.0100**	**0.0198**	**0.0296**	**0.0392**	**0.0488**	**0.0583**	**0.0677**	**0.0770**	**0.0862**
1.1	0.0953	0.1044	0.1133	0.1222	0.1310	0.1398	0.1484	0.1570	0.1655	0.1740
1.2	0.1823	0.1906	0.1989	0.2070	0.2151	0.2231	0.2311	0.2390	0.2469	0.2546
1.3	0.2624	0.2700	0.2776	0.2852	0.2927	0.3001	0.3075	0.3148	0.3221	0.3293
1.4	0.3365	0.3436	0.3507	0.3577	0.3646	0.3716	0.3784	0.3853	0.3920	0.3988
1.5	0.4055	0.4121	0.4187	0.4253	0.4318	0.4383	0.4447	0.4511	0.4574	0.4637
1.6	0.4700	0.4762	0.4824	0.4886	0.4947	0.5008	0.5068	0.5128	0.5188	0.5247
1.7	0.5306	0.5365	0.5423	0.5481	0.5539	0.5596	0.5653	0.5710	0.5766	0.5822
1.8	0.5878	0.5933	0.5988	0.6043	0.6098	0.6152	0.6206	0.6259	0.6313	0.6366
1.9	0.6419	0.6471	0.6523	0.6575	0.6627	0.6678	0.6729	0.6780	0.6831	0.6881
2.0	**0.6931**	**0.6981**	**0.7031**	**0.7080**	**0.7129**	**0.7178**	**0.7227**	**0.7275**	**0.7324**	**0.7372**
2.1	0.7419	0.7467	0.7514	0.7561	0.7608	0.7655	0.7701	0.7747	0.7793	0.7839
2.2	0.7885	0.7930	0.7975	0.8020	0.8065	0.8109	0.8154	0.8198	0.8242	0.8286
2.3	0.8329	0.8372	0.8416	0.8459	0.8502	0.8544	0.8587	0.8629	0.8671	0.8713
2.4	0.8755	0.8796	0.8838	0.8879	0.8920	0.8961	0.9002	0.9042	0.9083	0.9123
2.5	0.9163	0.9203	0.9243	0.9282	0.9322	0.9361	0.9400	0.9439	0.9478	0.9517
2.6	0.9555	0.9594	0.9632	0.9670	0.9708	0.9746	0.9783	0.9821	0.9858	0.9895
2.7	0.9933	0.9969	1.0006	1.0043	1.0080	1.0116	1.0152	1.0188	1.0225	1.0260
2.8	1.0296	1.0332	1.0367	1.0403	1.0438	1.0473	1.0508	1.0543	1.0578	1.0613
2.9	1.0647	1.0682	1.0716	1.0750	1.0784	1.0818	1.0852	1.0886	1.0919	1.0953
3.0	**1.0986**	**1.1019**	**1.1053**	**1.1086**	**1.1119**	**1.1151**	**1.1184**	**1.1217**	**1.1249**	**1.1282**
3.1	1.1314	1.1346	1.1378	1.1410	1.1442	1.1474	1.1506	1.1537	1.1569	1.1600
3.2	1.1632	1.1663	1.1694	1.1725	1.1756	1.1787	1.1817	1.1848	1.1878	1.1909
3.3	1.1939	1.1969	1.2000	1.2030	1.2060	1.2090	1.2119	1.2149	1.2179	1.2208
3.4	1.2238	1.2267	1.2296	1.2326	1.2355	1.2384	1.2413	1.2442	1.2470	1.2499
3.5	1.2528	1.2556	1.2585	1.2613	1.2641	1.2669	1.2698	1.2726	1.2754	1.2782
3.6	1.2809	1.2837	1.2865	1.2892	1.2920	1.2947	1.2975	1.3002	1.3029	1.3056
3.7	1.3083	1.3110	1.3137	1.3164	1.3191	1.3218	1.3244	1.3271	1.3297	1.3324
3.8	1.3350	1.3376	1.3403	1.3429	1.3455	1.3481	1.3507	1.3533	1.3558	1.3584
3.9	1.3610	1.3635	1.3661	1.3686	1.3712	1.3737	1.3762	1.3788	1.3813	1.3838
4.0	**1.3863**	**1.3888**	**1.3913**	**1.3938**	**1.3962**	**1.3987**	**1.4012**	**1.4036**	**1.4061**	**1.4085**
4.1	1.4110	1.4134	1.4159	1.4183	1.4207	1.4231	1.4255	1.4279	1.4303	1.4327
4.2	1.4351	1.4375	1.4398	1.4422	1.4446	1.4469	1.4493	1.4516	1.4540	1.4563
4.3	1.4586	1.4609	1.4633	1.4656	1.4679	1.4702	1.4725	1.4748	1.4770	1.4793
4.4	1.4816	1.4839	1.4861	1.4884	1.4907	1.4929	1.4951	1.4974	1.4996	1.5019
4.5	1.5041	1.5063	1.5085	1.5107	1.5129	1.5151	1.5173	1.5195	1.5217	1.5239
4.6	1.5261	1.5282	1.5304	1.5326	1.5347	1.5369	1.5390	1.5412	1.5433	1.5454
4.7	1.5476	1.5497	1.5518	1.5539	1.5560	1.5581	1.5602	1.5623	1.5644	1.5665
4.8	1.5686	1.5707	1.5728	1.5748	1.5769	1.5790	1.5810	1.5831	1.5851	1.5872
4.9	1.5892	1.5913	1.5933	1.5953	1.5974	1.5994	1.6014	1.6034	1.6054	1.6074

NATURAL LOGARITHMS (*continued*)

N	0	1	2	3	4	5	6	7	8	9
5.0	**1.6094**	**1.6114**	**1.6134**	**1.6154**	**1.6174**	**1.6194**	**1.6214**	**1.6233**	**1.6253**	**1.6273**
5.1	1.6292	1.6312	1.6332	1.6351	1.6371	1.6390	1.6409	1.6429	1.6448	1.6467
5.2	1.6487	1.6506	1.6525	1.6544	1.6563	1.6582	1.6601	1.6620	1.6639	1.6658
5.3	1.6677	1.6696	1.6715	1.6734	1.6752	1.6771	1.6790	1.6808	1.6827	1.6845
5.4	1.6864	1.6882	1.6901	1.6919	1.6938	1.6956	1.6974	1.6993	1.7011	1.7029
5.5	1.7047	1.7066	1.7084	1.7102	1.7120	1.7138	1.7156	1.7174	1.7192	1.7210
5.6	1.7228	1.7246	1.7263	1.7281	1.7299	1.7317	1.7334	1.7352	1.7370	1.7387
5.7	1.7405	1.7422	1.7440	1.7457	1.7475	1.7492	1.7509	1.7527	1.7544	1.7561
5.8	1.7579	1.7596	1.7613	1.7630	1.7647	1.7664	1.7681	1.7699	1.7716	1.7733
5.9	1.7750	1.7766	1.7783	1.7800	1.7817	1.7834	1.7851	1.7867	1.7884	1.7901
6.0	**1.7918**	**1.7934**	**1.7951**	**1.7967**	**1.7984**	**1.8001**	**1.8017**	**1.8034**	**1.8050**	**1.8066**
6.1	1.8083	1.8099	1.8116	1.8132	1.8148	1.8165	1.8181	1.8197	1.8213	1.8229
6.2	1.8245	1.8262	1.8278	1.8294	1.8310	1.8326	1.8342	1.8358	1.8374	1.8390
6.3	1.8405	1.8421	1.8437	1.8453	1.8469	1.8485	1.8500	1.8516	1.8532	1.8547
6.4	1.8563	1.8579	1.8594	1.8610	1.8625	1.8641	1.8656	1.8672	1.8687	1.8703
6.5	1.8718	1.8733	1.8749	1.8764	1.8779	1.8795	1.8810	1.8825	1.8840	1.8856
6.6	1.8871	1.8886	1.8901	1.8916	1.8931	1.8946	1.8961	1.8976	1.8991	1.9006
6.7	1.9021	1.9036	1.9051	1.9066	1.9081	1.9095	1.9110	1.9125	1.9140	1.9155
6.8	1.9169	1.9184	1.9199	1.9213	1.9228	1.9242	1.9257	1.9272	1.9286	1.9301
6.9	1.9315	1.9330	1.9344	1.9359	1.9373	1.9387	1.9402	1.9416	1.9430	1.9445
7.0	**1.9459**	**1.9473**	**1.9488**	**1.9502**	**1.9516**	**1.9530**	**1.9544**	**1.9559**	**1.9573**	**1.9587**
7.1	1.9601	1.9615	1.9629	1.9643	1.9657	1.9671	1.9685	1.9699	1.9713	1.9727
7.2	1.9741	1.9755	1.9769	1.9782	1.9796	1.9810	1.9824	1.9838	1.9851	1.9865
7.3	1.9879	1.9892	1.9906	1.9920	1.9933	1.9947	1.9961	1.9974	1.9988	2.0001
7.4	2.0015	2.0028	2.0042	2.0055	2.0069	2.0082	2.0096	2.0109	2.0122	2.0136
7.5	2.0149	2.0162	2.0176	2.0189	2.0202	2.0215	2.0229	2.0242	2.0255	2.0268
7.6	2.0281	2.0295	2.0308	2.0321	2.0334	2.0347	2.0360	2.0373	2.0386	2.0399
7.7	2.0412	2.0425	2.0438	2.0451	2.0464	2.0477	2.0490	2.0503	2.0516	2.0528
7.8	2.0541	2.0554	2.0567	2.0580	2.0592	2.0605	2.0618	2.0631	2.0643	2.0656
7.9	2.0669	2.0681	2.0694	2.0707	2.0719	2.0732	2.0744	2.0757	2.0769	2.0782
8.0	**2.0794**	**2.0807**	**2.0819**	**2.0832**	**2.0844**	**2.0857**	**2.0869**	**2.0882**	**2.0894**	**2.0906**
8.1	2.0919	2.0931	2.0943	2.0956	2.0968	2.0980	2.0992	2.1005	2.1017	2.1029
8.2	2.1041	2.1054	2.1066	2.1078	2.1090	2.1102	2.1114	2.1126	2.1138	2.1150
8.3	2.1163	2.1175	2.1187	2.1199	2.1211	2.1223	2.1235	2.1247	2.1258	2.1270
8.4	2.1282	2.1294	2.1306	2.1318	2.1330	2.1342	2.1353	2.1365	2.1377	2.1389
8.5	2.1401	2.1412	2.1424	2.1436	2.1448	2.1459	2.1471	2.1483	2.1494	2.1506
8.6	2.1518	2.1529	2.1541	2.1552	2.1564	2.1576	2.1587	2.1599	2.1610	2.1622
8.7	2.1633	2.1645	2.1656	2.1668	2.1679	2.1691	2.1702	2.1713	2.1725	2.1736
8.8	2.1748	2.1759	2.1770	2.1782	2.1793	2.1804	2.1815	2.1827	2.1838	2.1849
8.9	2.1861	2.1872	2.1883	2.1894	2.1905	2.1917	2.1928	2.1939	2.1950	2.1961
9.0	**2.1972**	**2.1983**	**2.1994**	**2.2006**	**2.2017**	**2.2028**	**2.2039**	**2.2050**	**2.2061**	**2.2072**
9.1	2.2083	2.2094	2.2105	2.2116	2.2127	2.2138	2.2148	2.2159	2.2170	2.2181
9.2	2.2192	2.2203	2.2214	2.2225	2.2235	2.2246	2.2257	2.2268	2.2279	2.2289
9.3	2.2300	2.2311	2.2322	2.2332	2.2343	2.2354	2.2364	2.2375	2.2386	2.2396
9.4	2.2407	2.2418	2.2428	2.2439	2.2450	2.2460	2.2471	2.2481	2.2492	2.2502
9.5	2.2513	2.2523	2.2534	2.2544	2.2555	2.2565	2.2576	2.2586	2.2597	2.2607
9.6	2.2618	2.2628	2.2638	2.2649	2.2659	2.2670	2.2680	2.2690	2.2701	2.2711
9.7	2.2721	2.2732	2.2742	2.2752	2.2762	2.2773	2.2783	2.2793	2.2803	2.2814
9.8	2.2824	2.2834	2.2844	2.2854	2.2865	2.2875	2.2885	2.2895	2.2905	2.2915
9.9	2.2925	2.2935	2.2946	2.2956	2.2966	2.2976	2.2986	2.2996	2.3006	2.3016

COMMON LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	*4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	*3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

* Interpolation in this section of the table is inaccurate.

LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts								
											1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

SQUARE ROOTS

(Moving the decimal point TWO places in n is equivalent to moving it ONE place in $\sqrt{n}$)

n	0	1	2	3	4	5	6	7	8	9	10	Tenths of the Tabular Difference				
												1	2	3	4	5
.1	.316	.332	.346	.361	.374	.387						1	3	4	6	7
						[illegible]	.400	.412	.424	.436	.447	1	2	4	5	6
.2	.447	.458	.469	.480	.490	.500	.510	.520	.529	.539	.548	1	2	3	4	5
.3	.548	.557	.566	.574	.583	.592	.600	.608	.616	.624	.632	1	2	3	3	4
.4	.632	.640	.648	.656	.663	.671	.678	.686	.693	.700	.707	1	1	2	3	4
.5	.707	.714	.721	.728	.735	.742	.748	.755	.762	.768	.775	1	1	2	3	3
.6	.775	.781	.787	.794	.800	.806	.812	.819	.825	.831	.837	1	1	2	2	3
.7	.837	.843	.849	.854	.860	.866	.872	.877	.883	.889	.894	1	1	2	2	3
.8	.894	.900	.906	.911	.917	.922	.927	.933	.938	.943	0.949	1	1	2	2	3
.9	0.949	0.954	0.959	0.964	0.970	0.975	0.980	0.985	0.990	0.995	1.000	1	1	2	2	3
1.0	1.000	1.005	1.010	1.015	1.020	1.025	1.030	1.034	1.039	1.044	1.049	0	1	1	2	2
1.1	1.049	1.054	1.058	1.063	1.068	1.072	1.077	1.082	1.086	1.091	1.095	0	1	1	2	2
1.2	1.095	1.100	1.105	1.109	1.114	1.118	1.122	1.127	1.131	1.136	1.140	0	1	1	2	2
1.3	1.140	1.145	1.149	1.153	1.158	1.162	1.166	1.170	1.175	1.179	1.183	0	1	1	2	2
1.4	1.183	1.187	1.192	1.196	1.200	1.204	1.208	1.212	1.217	1.221	1.225	0	1	1	2	2
1.5	1.225	1.229	1.233	1.237	1.241	1.245	1.249	1.253	1.257	1.261	1.265	0	1	1	2	2
1.6	1.265	1.269	1.273	1.277	1.281	1.285	1.288	1.292	1.296	1.300	1.304	0	1	1	2	2
1.7	1.304	1.308	1.311	1.315	1.319	1.323	1.327	1.330	1.334	1.338	1.342	0	1	1	2	2
1.8	1.342	1.345	1.349	1.353	1.356	1.360	1.364	1.367	1.371	1.375	1.378	0	1	1	1	2
1.9	1.378	1.382	1.386	1.389	1.393	1.396	1.400	1.404	1.407	1.411	1.414	0	1	1	1	2
2.0	1.414	1.418	1.421	1.425	1.428	1.432	1.435	1.439	1.442	1.446	1.449	0	1	1	1	2
2.1	1.449	1.453	1.456	1.459	1.463	1.466	1.470	1.473	1.476	1.480	1.483	0	1	1	1	2
2.2	1.483	1.487	1.490	1.493	1.497	1.500	1.503	1.507	1.510	1.513	1.517	0	1	1	1	2
2.3	1.517	1.520	1.523	1.526	1.530	1.533	1.536	1.539	1.543	1.546	1.549	0	1	1	1	2
2.4	1.549	1.552	1.556	1.559	1.562	1.565	1.568	1.572	1.575	1.578	1.581	0	1	1	1	2
2.5	1.581	1.584	1.587	1.591	1.594	1.597	1.600	1.603	1.606	1.609	1.612	0	1	1	1	2
2.6	1.612	1.616	1.619	1.622	1.625	1.628	1.631	1.634	1.637	1.640	1.643	0	1	1	1	2
2.7	1.643	1.646	1.649	1.652	1.655	1.658	1.661	1.664	1.667	1.670	1.673	0	1	1	1	2
2.8	1.673	1.676	1.679	1.682	1.685	1.688	1.691	1.694	1.697	1.700	1.703	0	1	1	1	1
2.9	1.703	1.706	1.709	1.712	1.715	1.718	1.720	1.723	1.726	1.729	1.732	0	1	1	1	1
3.0	1.732	1.735	1.738	1.741	1.744	1.746	1.749	1.752	1.755	1.758	1.761	0	1	1	1	1
3.1	1.761	1.764	1.766	1.769	1.772	1.775	1.778	[illegible]80	1.783	1.786	1.789	0	1	1	1	1
3.2	1.789	1.792	1.794	1.797	1.800	1.803	1.806	1.808	1.811	1.814	1.817	0	1	1	1	1
3.3	1.817	1.819	1.822	1.825	1.828	1.830	1.833	1.836	1.838	1.841	1.844	0	1	1	1	1
3.4	1.844	1.847	1.849	1.852	1.855	1.857	1.860	1.863	1.865	1.868	1.871	0	1	1	1	1
3.5	1.871	1.873	1.876	1.879	1.881	1.884	1.887	1.889	1.892	1.895	1.897	0	1	1	1	1
3.6	1.897	1.900	1.903	1.905	1.908	1.910	1.913	1.916	1.918	1.921	1.924	0	1	1	1	1
3.7	1.924	1.926	1.929	1.931	1.934	1.936	1.939	1.942	1.944	1.947	1.949	0	1	1	1	1
3.8	1.949	1.952	1.954	1.957	1.960	1.962	1.965	1.967	1.970	1.972	1.975	0	1	1	1	1
3.9	1.975	1.977	1.980	1.982	1.985	1.987	1.990	1.992	1.995	1.997	2.000	0	1	1	1	1
4.0	2.000	2.002	2.005	2.007	2.010	2.012	2.015	2.017	2.020	2.022	2.025	0	0	1	1	1
4.1	2.025	2.027	2.030	2.032	2.035	2.037	2.040	2.042	2.045	2.047	2.049	0	0	1	1	1
4.2	2.049	2.052	2.054	2.057	2.059	2.062	2.064	2.066	2.069	2.071	2.074	0	0	1	1	1
4.3	2.074	2.076	2.078	2.081	2.083	2.086	2.088	2.090	2.093	2.095	2.098	0	0	1	1	1
4.4	2.098	2.100	2.102	2.105	2.107	2.110	2.112	2.114	2.117	2.119	2.121	0	0	1	1	1
4.5	2.121	2.124	2.126	2.128	2.131	2.133	2.135	2.138	2.140	2.142	2.145	0	0	1	1	1
4.6	2.145	2.147	2.149	2.152	2.154	2.156	2.159	2.161	2.163	2.166	2.168	0	0	1	1	1
4.7	2.168	2.170	2.173	2.175	2.177	2.179	2.182	2.184	2.186	2.189	2.191	0	0	1	1	1
4.8	2.191	2.193	2.195	2.198	2.200	2.202	2.205	2.207	2.209	2.211	2.214	0	0	1	1	1
4.9	2.214	2.216	2.218	2.220	2.223	2.225	2.227	2.229	2.232	2.234	2.236	0	0	1	1	1
5.	2.236	2.258	2.280	2.302	2.324	2.345	2.366	2.387	2.408	2.429	2.449	2	4	6	9	11
6.	2.449	2.470	2.490	2.510	2.530	2.550	2.569	2.588	2.608	2.627	2.646	2	4	6	8	10
7.	2.646	2.665	2.683	2.702	2.720	2.739	2.757	2.775	2.793	2.811	2.828	2	4	5	7	9
8.	2.828	2.846	2.864	2.881	2.898	2.915	2.933	2.950	2.966	2.983	3.000	2	3	5	7	9
9.	3.000	3.017	3.033	3.050	3.066	3.082	3.098	3.114	3.130	3.146	3.162	2	3	5	6	8

$\sqrt{\pi} = 1.772454$ $\sqrt{1/\pi} = 0.56419$

SQUARES

(Moving the decimal point ONE place in n is equivalent to moving it TWO places in n^2)

												Tenths of the Tabular Difference				
n	0	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5
1.0	1.000	1.020	1.040	1.061	1.082	1.103	1.124	1.145	1.166	1.188	1.210	2	4	6	8	10
1.1	1.210	1.232	1.254	1.277	1.300	1.323	1.346	1.369	1.392	1.416	1.440	2	5	7	9	11
1.2	1.440	1.464	1.488	1.513	1.538	1.563	1.588	1.613	1.638	1.664	1.690	2	5	7	10	12
1.3	1.690	1.716	1.742	1.769	1.796	1.823	1.850	1.877	1.904	1.932	1.960	3	5	8	11	13
1.4	1.960	1.988	2.016	2.045	2.074	2.103	2.132	2.161	2.190	2.220	2.250	3	6	9	12	14
1.5	2.250	2.280	2.310	2.341	2.372	2.403	2.434	2.465	2.496	2.528	2.560	3	6	9	12	15
1.6	2.560	2.592	2.624	2.657	2.690	2.723	2.756	2.789	2.822	2.856	2.890	3	7	10	13	16
1.7	2.890	2.924	2.958	2.993	3.028	3.063	3.098	3.133	3.168	3.204	3.240	3	7	10	14	17
1.8	3.240	3.276	3.312	3.349	3.386	3.423	3.460	3.497	3.534	3.572	3.610	4	7	11	15	18
1.9	3.61	3.65	3.69	3.72	3.76	3.80	3.84	3.88	3.92	3.96	4.00	0	1	1	2	2
2.0	4.00	4.04	4.08	4.12	4.16	4.20	4.24	4.28	4.33	4.37	4.41	0	1	1	2	2
2.1	4.41	4.45	4.49	4.54	4.58	4.62	4.67	4.71	4.75	4.80	4.84	0	1	1	2	2
2.2	4.84	4.88	4.93	4.97	5.02	5.06	5.11	5.15	5.20	5.24	5.29	0	1	1	2	2
2.3	5.29	5.34	5.38	5.43	5.48	5.52	5.57	5.62	5.66	5.71	5.76	0	1	1	2	2
2.4	5.76	5.81	5.86	5.90	5.95	6.00	6.05	6.10	6.15	6.20	6.25	0	1	1	2	2
2.5	6.25	6.30	6.35	6.40	6.45	6.50	6.55	6.60	6.66	6.71	6.76	1	1	2	2	3
2.6	6.76	6.81	6.86	6.92	6.97	7.02	7.08	7.13	7.18	7.24	7.29	1	1	2	2	3
2.7	7.29	7.34	7.40	7.45	7.51	7.56	7.62	7.67	7.73	7.78	7.84	1	1	2	2	3
2.8	7.84	7.90	7.95	8.01	8.07	8.12	8.18	8.24	8.29	8.35	8.41	1	1	2	2	3
2.9	8.41	8.47	8.53	8.58	8.64	8.70	8.76	8.82	8.88	8.94	9.00	1	1	2	2	3
3.0	9.00	9.06	9.12	9.18	9.24	9.30	9.36	9.42	9.49	9.55	9.61	1	1	2	2	3
3.1	9.61	9.67	9.73	9.80	9.86	9.92	9.99	10.05	10.11	10.18	10.24	1	1	2	3	3
3.2	10.24	10.30	10.37	10.43	10.50	10.56	10.63	10.69	10.76	10.82	10.89	1	1	2	3	3
3.3	10.89	10.96	11.02	11.09	11.16	11.22	11.29	11.36	11.42	11.49	11.56	1	1	2	3	3
3.4	11.56	11.63	11.70	11.76	11.83	11.90	11.97	12.04	12.11	12.18	12.25	1	1	2	3	3
3.5	12.25	12.32	12.39	12.46	12.53	12.60	12.67	12.74	12.82	12.89	12.96	1	1	2	3	4
3.6	12.96	13.03	13.10	13.18	13.25	13.32	13.40	13.47	13.54	13.62	13.69	1	1	2	3	4
3.7	13.69	13.76	13.84	13.91	13.99	14.06	14.14	14.21	14.29	14.36	14.44	1	1	2	3	4
3.8	14.44	14.52	14.59	14.67	14.75	14.82	14.90	14.98	15.05	15.13	15.21	1	2	2	3	4
3.9	15.21	15.29	15.37	15.44	15.52	15.60	15.68	15.76	15.84	15.92	16.00	1	2	2	3	4
4.0	16.00	16.08	16.16	16.24	16.32	16.40	16.48	16.56	16.65	16.73	16.81	1	2	2	3	4
4.1	16.81	16.89	16.97	17.06	17.14	17.22	17.31	17.39	17.47	17.56	17.64	1	2	2	3	4
4.2	17.64	17.72	17.81	17.89	17.98	18.06	18.15	18.23	18.32	18.40	18.49	1	2	3	3	4
4.3	18.49	18.58	18.66	18.75	18.84	18.92	19.01	19.10	19.18	19.27	19.36	1	2	3	3	4
4.4	19.36	19.45	19.54	19.62	19.71	19.80	19.89	19.98	20.07	20.16	20.25	1	2	3	4	4
4.5	20.25	20.34	20.43	20.52	20.61	20.70	20.79	20.88	20.98	21.07	21.16	1	2	3	4	5
4.6	21.16	21.25	21.34	21.44	21.53	21.62	21.72	21.81	21.90	22.00	22.09	1	2	3	4	5
4.7	22.09	22.18	22.28	22.37	22.47	22.56	22.66	22.75	22.85	22.94	23.04	1	2	3	4	5
4.8	23.04	23.14	23.23	23.33	23.43	23.52	23.62	23.72	23.81	23.91	24.01	1	2	3	4	5
4.9	24.01	24.11	24.21	24.30	24.40	24.50	24.60	24.70	24.80	24.90	25.00	1	2	3	4	5
5.0	25.00	25.10	25.20	25.30	25.40	25.50	25.60	25.70	25.81	25.91	26.01	1	2	3	4	5
5.1	26.01	26.11	26.21	26.32	26.42	26.52	26.63	26.73	26.83	26.94	27.04	1	2	3	4	5
5.2	27.04	27.14	27.25	27.35	27.46	27.56	27.67	27.77	27.88	27.98	28.09	1	2	3	4	5
5.3	28.09	28.20	28.30	28.41	28.52	28.62	28.73	28.84	28.94	29.05	29.16	1	2	3	4	5
5.4	29.16	29.27	29.38	29.48	29.59	29.70	29.81	29.92	30.03	30.14	30.25	1	2	3	4	5
5.5	30.25	30.36	30.47	30.58	30.69	30.80	30.91	31.02	31.14	31.25	31.36	1	2	3	4	6
5.6	31.36	31.47	31.58	31.70	31.81	31.92	32.04	32.15	32.26	32.38	32.49	1	2	3	5	6
5.7	32.49	32.60	32.72	32.83	32.95	33.06	33.18	33.29	33.41	33.52	33.64	1	2	3	5	6
5.8	33.64	33.76	33.87	33.99	34.11	34.22	34.34	34.46	34.57	34.69	34.81	1	2	4	5	6
5.9	34.81	34.93	35.05	35.16	35.28	35.40	35.52	35.64	35.76	35.88	36.00	1	2	4	5	6
6.	36.0	37.2	38.4	39.7	41.0	42.3	43.6	44.9	46.2	47.6	49.0	1	3	4	5	6
7.	49.0	50.4	51.8	53.3	54.8	56.3	57.8	59.3	60.8	62.4	64.0	1	3	4	6	7
8.	64.0	65.6	67.2	68.9	70.6	72.3	74.0	75.7	77.4	79.2	81.0	2	3	5	7	8
9.	81.0	82.8	84.6	86.5	88.4	90.3	92.2	94.1	96.0	98.0	100.0	2	4	6	8	9

$\pi^2 = 9.870$ $1/\pi^2 = 0.10132$

VALUES AND LOGARITHMS OF EXPONENTIAL FUNCTIONS

x	e^x		e^{-x}	x	e^x		e^{-x}
	Value	$\log_{10}$	Value		Value	$\log_{10}$	Value
0.00	1.0000	.00000	1.00000	0.50	1.6487	.21715	.60653
0.01	1.0101	.00434	.99005	0.51	1.6653	.22149	.60050
0.02	1.0202	.00869	.98020	0.52	1.6820	.22583	.59452
0.03	1.0305	.01303	.97045	0.53	1.6989	.23018	.58860
0.04	1.0408	.01737	.96079	0.54	1.7160	.23452	.58275
0.05	1.0513	.02171	.95123	0.55	1.7333	.23886	.57695
0.06	1.0618	.02606	.94176	0.56	1.7507	.24320	.57121
0.07	1.0725	.03040	.93239	0.57	1.7683	.24755	.56553
0.08	1.0833	.03474	.92312	0.58	1.7860	.25189	.55990
0.09	1.0942	03909	.91393	0.59	1.8040	.25623	.55433
0.10	1.1052	.04343	.90484	0.60	1.8221	.26058	.54881
0.11	1.1163	.04777	.89583	0.61	1.8404	.26492	.54335
0.12	1.1275	.05212	.88692	0.62	1.8589	.26926	.53794
0.13	1.1388	.05646	.87809	0.63	1.8776	.27361	.53259
0.14	1.1503	.06080	.86936	0.64	1.8965	.27795	.52729
0.15	1.1618	.06514	.86071	0.65	1.9155	.28229	.52205
0.16	1.1735	.06949	.85214	0.66	1.9348	.28664	.51685
0.17	1.1853	.07383	.84366	0.67	1.9542	.29098	.51171
0.18	1.1972	.07817	.83527	0.68	1.9739	.29532	.50662
0.19	1.2092	.08252	.82696	0.69	1.9937	.29966	.50158
0.20	1.2214	.08686	.81873	0.70	2.0138	.30401	.49659
0.21	1.2337	.09120	.81058	0.71	2.0340	.30835	.49164
0.22	1.2461	.09554	.80252	0.72	2.0544	.31269	.48675
0.23	1.2586	.09989	.79453	0.73	2.0751	.31703	.48191
0.24	1.2712	.10423	.78663	0.74	2.0959	.32138	.47711
0.25	1.2840	.10857	.77880	0.75	2.1170	.32572	.47237
0.26	1.2969	.11292	.77105	0.76	2.1383	.33006	.46767
0.27	1.3100	.11726	.76338	0.77	2.1598	.33441	.46301
0.28	1.3231	.12160	.75578	0.78	2.1815	.33875	.45841
0.29	1.3364	.12595	.74826	0.79	2.2034	.34309	.45384
0.30	1.3499	.13029	.74082	0.80	2.2255	.34744	.44933
0.31	1.3634	.13463	.73345	0.81	2.2479	.35178	.44486
0.32	1.3771	.13897	.72615	0.82	2.2705	.35612	.44043
0.33	1.3910	.14332	.71892	0.83	2.2933	.36046	.43605
0.34	1.4049	.14766	.71177	0.84	2.3164	.36481	.43171
0.35	1.4191	.15200	.70469	0.85	2.3396	.36915	.42741
0.36	1.4333	.15635	.69768	0.86	2.3632	.37349	.42316
0.37	1.4477	.16069	.69073	0.87	2.3869	.37784	.41895
0.38	1.4623	.16503	.68386	0.88	2.4109	.38218	.41478
0.39	1.4770	.16937	.67706	0.89	2.4351	.38652	.41066
0.40	1.4918	.17372	.67032	0.90	2.4596	.39087	.40657
0.41	1.5068	.17806	.66365	0.91	2.4843	.39521	.40252
0.42	1.5220	.18240	.65705	0.92	2.5093	.39955	.39852
0.43	1.5373	.18675	.65051	0.93	2.5345	.40389	.39455
0.44	1.5527	.19109	.64404	0.94	2.5600	.40824	.39063
0.45	1.5683	.19543	.63763	0.95	2.5857	.41258	.38674
0.46	1.5841	.19978	.63128	0.96	2.6117	.41692	.38289
0.47	1.6000	.20412	.62500	0.97	2.6379	.42127	.37908
0.48	1.6161	.20846	.61878	0.98	2.6645	.42561	.37531
0.49	1.6323	.21280	.61263	0.99	2.6912	.42995	.37158
0.50	1.6487	.21715	.60653	1.00	2.7183	.43429	.36788

x	e^x		e^{-x}	x	e^x		e^{-x}
	Value	Log_{10}	Value		Value	Log_{10}	Value
1.00	2.7183	.43429	.36788	1.50	4.4817	.65144	.22313
1.01	2.7456	.43864	.36422	1.51	4.5267	.65578	.22091
1.02	2.7732	.44298	.36060	1.52	4.5722	.66013	.21871
1.03	2.8011	.44732	.35701	1.53	4.6182	.66447	.21654
1.04	2.8292	.45167	.35345	1.54	4.6646	.66881	.21438
1.05	2.8577	.45601	.34994	1.55	4.7115	.67316	.21225
1.06	2.8864	.46035	.34646	1.56	4.7588	.67750	.21014
1.07	2.9154	.46470	.34301	1.57	4.8066	.68184	.20805
1.08	2.9447	.46904	.33960	1.58	4.8550	.68619	.20598
1.09	2.9743	.47338	.33622	1.59	4.9037	.69053	.20393
1.10	3.0042	.47772	.33287	1.60	4.9530	.69487	.20190
1.11	3.0344	.48207	.32956	1.61	5.0028	.69921	.19989
1.12	3.0649	.48641	.32628	1.62	5.0531	.70356	.19790
1.13	3.0957	.49075	.32303	1.63	5.1039	.70790	.19593
1.14	3.1268	.49510	.31982	1.64	5.1552	.71224	.19398
1.15	3.1582	.49944	.31664	1.65	5.2070	.71659	.19205
1.16	3.1899	.50378	.31349	1.66	5.2593	.72093	.19014
1.17	3.2220	.50812	.31037	1.67	5.3122	.72527	.18825
1.18	3.2544	.51247	.30728	1.68	5.3656	.72961	.18637
1.19	3.2871	.51681	.30422	1.69	5.4195	.73396	.18452
1.20	3.3201	.52115	.30119	1.70	5.4739	.73830	.18268
1.21	3.3535	.52550	.29820	1.71	5.5290	.74264	.18087
1.22	3.3872	.52984	.29523	1.72	5.5845	.74699	.17907
1.23	3.4212	.53418	.29229	1.73	5.6407	.75133	.17728
1.24	3.4556	.53853	.28938	1.74	5.6973	.75567	.17552
1.25	3.4903	.54287	.28650	1.75	5.7546	.76002	.17377
1.26	3.5254	.54721	.28365	1.76	5.8124	.76436	.17204
1.27	3.5609	.55155	.28073	1.77	5.8709	.76870	.17033
1.28	3.5966	.55590	.27804	1.78	5.9299	.77304	.16864
1.29	3.6328	.56024	.27527	1.79	5.9895	.77739	.16696
1.30	3.6693	.56458	.27253	1.80	6.0496	.78173	.16530
1.31	3.7062	.56893	.26982	1.81	6.1104	.78607	.16365
1.32	3.7434	.57327	.26714	1.82	6.1719	.79042	.16203
1.33	3.7810	.57761	.26448	1.83	6.2339	.79476	.16041
1.34	3.8190	.58195	.26185	1.84	6.2965	.79910	.15882
1.35	3.8574	.58630	.25924	1.85	6.3598	.80344	.15724
1.36	3.8962	.59064	.25666	1.86	6.4237	.80779	.15567
1.37	3.9354	.59498	.25411	1.87	6.4883	.81213	.15412
1.38	3.9749	.59933	.25158	1.88	6.5535	.81647	.15259
1.39	4.0149	.60367	.24908	1.89	6.6194	.82082	.15107
1.40	4.0552	.60801	.24660	1.90	6.6859	.82516	.14957
1.41	4.0960	.61236	.24414	1.91	6.7531	.82950	.14808
1.42	4.1371	.61670	.24171	1.92	6.8210	.83385	14661
1.43	4.1787	.62104	.23931	1.93	6.8895	.83819	.14515
1.44	4.2207	.62538	.23693	1.94	6.9588	.84253	.14370
1.45	4.2631	.62973	.23457	1.95	7.0287	.84687	.14227
1.46	4.3060	.63407	.23224	1.96	7.0993	.85122	.14086
1.47	4.3492	.63841	.22993	1.97	7.1707	.85556	.13946
1.48	4.3929	.64276	.22764	1.98	7.2427	.85990	.13807
1.49	4.4371	.64710	.22537	1.99	7.3155	.86425	.13670
1.50	4.4817	.65144	.22313	2.00	7.3891	.86859	.13534

x	e^x		e^{-x}	x	e^x		e^{-x}
	Value	Log_{10}	Value		Value	Log_{10}	Value
2.00	7.3891	.86859	.13534	2.50	12.182	1.08574	.08208
2.01	7.4633	.87293	.13399	2.51	12.305	1.09008	.08127
2.02	7.5383	.87727	.13266	2.52	12.429	1.09442	.08046
2.03	7.6141	.88162	.13134	2.53	12.554	1.09877	.07966
2.04	7.6906	.88596	.13003	2.54	12.680	1.10311	.07887
2.05	7.7679	.89030	.12873	2.55	12.807	1.10745	.07808
2.06	7.8460	.89465	.12745	2.56	12.936	1.11179	.07730
2.07	7.9248	.89899	.12619	2.57	13.066	1.11614	.07654
2.08	8.0045	.90333	.12493	2.58	13.197	1.12048	.07577
2.09	8.0849	.90768	.12369	2.59	13.330	1.12482	.07502
2.10	8.1662	.91202	.12246	2.60	13.464	1.12917	.07427
2.11	8.2482	.91636	.12124	2.61	13.599	1.13351	.07353
2.12	8.3311	.92070	.12003	2.62	13.736	1.13785	.07280
2.13	8.4149	.92505	.11884	2.63	13.874	1.14219	.07208
2.14	8.4994	.92939	.11765	2.64	14.013	1.14654	.07136
2.15	8.5849	.93373	.11648	2.65	14.154	1.15088	.07065
2.16	8.6711	.93808	.11533	2.66	14.296	1.15522	.06995
2.17	8.7583	.94242	.11418	2.67	14.440	1.15957	.06925
2.18	8.8463	.94676	.11304	2.68	14.585	1.16391	.06856
2.19	8.9352	.95110	.11192	2.69	14.732	1.16825	.06788
2.20	9.0250	.95545	.11080	2.70	14.880	1.17260	.06721
2.21	9.1157	.95979	.10970	2.71	15.029	1.17694	.06654
2.22	9.2073	.96413	.10861	2.72	15.180	1.18128	.06587
2.23	9.2999	.96848	.10753	2.73	15.333	1.18562	.06522
2.24	9.3933	.97282	.10646	2.74	15.487	1.18997	.06457
2.25	9.4877	.97716	.10540	2.75	15.643	1.19431	.06393
2.26	9.5831	.98151	.10435	2.76	15.800	1.19865	.06329
2.27	9.6794	.98585	.10331	2.77	15.959	1.20300	.06266
2.28	9.7767	.99019	.10228	2.78	16.119	1.20734	.06204
2.29	9.8749	.99453	.10127	2.79	16.281	1.21168	.06142
2.30	9.9742	.99888	.10026	2.80	16.445	1.21602	.06081
2.31	10.074	1.00322	.09926	2.81	16.610	1.22037	.06020
2.32	10.176	1.00756	.09827	2.82	16.777	1.22471	.05961
2.33	10.278	1.01191	.09730	2.83	16.945	1.22905	.05901
2.34	10.381	1.01625	.09633	2.84	17.116	1.23340	.05843
2.35	10.486	1.02059	.09537	2.85	17.288	1.23774	.05784
2.36	10.591	1.02493	.09442	2.86	17.462	1.24208	.05727
2.37	10.697	1.02928	.09348	2.87	17.637	1.24643	.05670
2.38	10.805	1.03362	.09255	2.88	17.814	1.25077	.05613
2.39	10.913	1.03796	.09163	2.89	17.993	1.25511	.05558
2.40	11.023	1.04231	.09072	2.90	18.174	1.25945	.05502
2.41	11.134	1.04665	.08982	2.91	18.357	1.26380	.05448
2.42	11.246	1.05099	.08892	2.92	18.541	1.26814	.05393
2.43	11.359	1.05534	.08804	2.93	18.728	1.27248	.05340
2.44	11.473	1.05968	.08716	2.94	18.916	1.27683	.05287
2.45	11.588	1.06402	.08629	2.95	19.106	1.28117	.05234
2.46	11.705	1.06836	.08543	2.96	19.298	1.28551	.05182
2.47	11.822	1.07271	.08458	2.97	19.492	1.28985	.05130
2.48	11.941	1.07705	.08374	2.98	19.688	1.29420	.05079
2.49	12.061	1.08139	.08291	2.99	19.886	1.29854	.05029
2.50	12.182	1.08574	.08208	3.00	20.086	1.30288	.04979

x	e^x		e^{-x}
	Value	$\log_{10}$	Value
3.00	20.086	1.30288	.04979
3.05	21.115	1.32460	.04736
3.10	22.198	1.34631	.04505
3.15	23.336	1.36803	.04285
3.20	24.533	1.38974	.04076
3.25	25.790	1.41146	.03877
3.30	27.113	1.43317	.03688
3.35	28.503	1.45489	.03508
3.40	29.964	1.47660	.03337
3.45	31.500	1.49832	.03175
3.50	33.115	1.52003	.03020
3.55	34.813	1.54175	.02872
3.60	36.598	1.56346	.02732
3.65	38.475	1.58517	.02599
3.70	40.447	1.60689	.02472
3.75	42.521	1.62860	.02352
3.80	44.701	1.65032	.02237
3.85	46.993	1.67203	.02128
3.90	49.402	1.69375	.02024
3.95	51.935	1.71546	.01925
4.00	54.598	1.73718	.01832
4.10	60.340	1.78061	.01657
4.20	66.686	1.82404	.01500
4.30	73.700	1.86747	.01357
4.40	81.451	1.91090	.01227
4.50	90.017	1.95433	.01111
4.60	99.484	1.99775	.01005
4.70	109.95	2.04118	.00910
4.80	121.51	2.08461	.00823
4.90	134.29	2.12804	.00745
5.00	148.41	2.17147	.00674
5.10	164.02	2.21490	.00610
5.20	181.27	2.25833	.00552
5.30	200.34	2.30176	.00499
5.40	221.41	2.34519	.00452
5.50	244.69	2.38862	.00409
5.60	270.43	2.43205	.00370
5.70	298.87	2.47548	.00335
5.80	330.30	2.51891	.00303
5.90	365.04	2.56234	.00274
6.00	403.43	2.60577	.00248
6.25	518.01	2.71434	.00193
6.50	665.14	2.82291	.00150
6.75	854.06	2.93149	.00117
7.00	1096.6	3.04006	.00091
7.50	1808.0	3.25721	.00055
8.00	2981.0	3.47436	.00034
8.50	4914.8	3.69150	.00020
9.00	8103.1	3.90865	.00012
9.50	13360.	4.12580	.00007
10.00	22026.	4.34294	.00005

TRIGONOMETRIC FUNCTIONS*

DEGREES	SINE		DEGREES	SINE	
0	0.00000	90	45	0.70711	45
1	0.01745	89	46	0.71934	44
2	0.03490	88	47	0.73135	43
3	0.05234	87	48	0.74314	42
4	0.06976	86	49	0.75471	41
5	0.08716	85	50	0.76604	40
6	0.10453	84	51	0.77715	39
7	0.12187	83	52	0.78801	38
8	0.13917	82	53	0.79864	37
9	0.15643	81	54	0.80902	36
10	0.17365	80	55	0.81915	35
11	0.19081	79	56	0.82904	34
12	0.20791	78	57	0.83867	33
13	0.22495	77	58	0.84805	32
14	0.24192	76	59	0.85717	31
15	0.25882	75	60	0.86603	30
16	0.27564	74	61	0.87462	29
17	0.29237	73	62	0.88295	28
18	0.30902	72	63	0.89101	27
19	0.32557	71	64	0.89879	26
20	0.34202	70	65	0.90631	25
21	0.35837	69	66	0.91355	24
22	0.37461	68	67	0.92050	23
23	0.39073	67	68	0.92718	22
24	0.40674	66	69	0.93358	21
25	0.42262	65	70	0.93969	20
26	0.43837	64	71	0.94552	19
27	0.45399	63	72	0.95106	18
28	0.46947	62	73	0.95630	17
29	0.48481	61	74	0.96126	16
30	0.50000	60	75	0.96593	15
31	0.51504	59	76	0.97030	14
32	0.52992	58	77	0.97437	13
33	0.54464	57	78	0.97815	12
34	0.55919	56	79	0.98163	11
35	0.57358	55	80	0.98481	10
36	0.58779	54	81	0.98769	9
37	0.60182	53	82	0.99027	8
38	0.61556	52	83	0.99255	7
39	0.62932	51	84	0.99452	6
40	0.64279	50	85	0.99619	5
41	0.65606	49	86	0.99756	4
42	0.66913	48	87	0.99863	3
43	0.68200	47	88	0.99939	2
44	0.69466	46	89	0.99985	1
45	0.70711	45	90	1.00000	0
	COSINE	DEGREES		COSINE	DEGREES

* For degrees indicated at the top of the page use the column headings at the top. For degrees indicated at the bottom use the column indications at the bottom.

TABLE OF PROBITS

In the body of the table is given the probit corresponding to each percentage listed along the left edge and top.

	0	1	2	3	4	5	6	7	8	9
0	...	2.674	2.946	3.119	3.249	3.355	3.445	3.524	3.595	3.659
10	3.718	3.773	3.825	3.874	3.920	3.964	4.006	4.046	4.085	4.122
20	4.158	4.194	4.228	4.261	4.294	4.326	4.357	4.387	4.417	4.447
30	4.476	4.504	4.532	4.560	4.587	4.615	4.642	4.668	4.695	4.721
40	4.747	4.773	4.798	4.824	4.849	4.874	4.900	4.925	4.950	4.975
50	5.000	5.025	5.050	5.075	5.100	5.126	5.151	5.176	5.202	5.227
60	5.253	5.279	5.305	5.332	5.358	5.385	5.413	5.440	5.468	5.496
70	5.524	5.553	5.583	5.613	5.643	5.674	5.706	5.739	5.772	5.806
80	5.842	5.878	5.915	5.954	5.994	6.036	6.080	6.126	6.175	6.227

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
90	6.282	6.287	6.293	6.299	6.305	6.311	6.317	6.323	6.329	6.335
91	6.341	6.347	6.353	6.359	6.366	6.372	6.379	6.385	6.392	6.398
92	6.405	6.412	6.419	6.426	6.433	6.440	6.447	6.454	6.461	6.468
93	6.476	6.483	6.491	6.498	6.506	6.514	6.522	6.530	6.538	6.546
94	6.555	6.563	6.572	6.580	6.589	6.598	6.607	6.616	6.626	6.635
95	6.645	6.655	6.665	6.675	6.685	6.695	6.706	6.717	6.728	6.739
96	6.751	6.762	6.774	6.787	6.799	6.812	6.825	6.838	6.852	6.866
97	6.881	6.896	6.911	6.927	6.943	6.960	6.977	6.995	7.014	7.033
98	7.054	7.075	7.097	7.120	7.144	7.170	7.197	7.226	7.257	7.290
99	7.326	7.366	7.409	7.457	7.512	7.576	7.652	7.748	7.878	8.090

SCALE OF 64

MULTIPLICATION TABLE

	0	1	2	3	4	5	6	7	8	9
0	0	64	128	192	256	320	384	448	512	576
10	640	704	768	832	896	960	1024	1088	1152	1216
20	1280	1344	1408	1472	1536	1600	1664	1728	1792	1856
30	1920	1984	2048	2112	2176	2240	2304	2368	2432	2496
40	2560	2624	2688	2752	2816	2880	2944	3008	3072	3136
50	3200	3264	3328	3392	3456	3520	3584	3648	3712	3776
60	3840	3904	3968	4032	4096	4160	4224	4288	4352	4416
70	4480	4544	4608	4672	4736	4800	4864	4928	4992	5056
80	5120	5184	5248	5312	5376	5440	5504	5568	5632	5696
90	5760	5824	5888	5952	6016	6080	6144	6208	6272	6336
100	6400	6464	6528	6592	6656	6720	6784	6848	6912	6976
110	7040	7104	7168	7232	7296	7360	7424	7488	7552	7616
120	7680	7744	7808	7872	7936	8000	8064	8128	8192	8256
130	8320	8384	8448	8512	8576	8640	8704	8768	8832	8896
140	8960	9024	9088	9152	9216	9280	9344	9408	9472	9536
150	9600	9664	9728	9792	9856	9920	9984	10048	10112	10176
160	10240	10304	10368	10432	10496	10560	10624	10688	10752	10816
170	10880	10944	11008	11072	11136	11200	11264	11328	11392	11456
180	11520	11584	11648	11712	11776	11840	11904	11968	12032	12096
190	12160	12224	12288	12352	12416	12480	12544	12608	12672	12736
200	12800	12864	12928	12992	13056	13120	13184	13248	13312	13376

SCALE OF 256

MULTIPLICATION TABLE

	0	1	2	3	4	5	6	7	8	9
0	0	256	512	768	1024	1280	1536	1792	2048	2304
10	2560	2816	3072	3328	3584	3840	4096	4352	4608	4864
20	5120	5376	5632	5888	6144	6400	6656	6912	7168	7424
30	7680	7936	8192	8448	8704	8960	9216	9472	9728	9984
40	10240	10496	10752	11008	11264	11520	11776	12032	12288	12544
50	12800	13056	13312	13568	13824	14080	14336	14592	14848	15104
60	15360	15616	15872	16128	16384	16640	16896	17152	17408	17664
70	17920	18176	18432	18688	18944	19200	19456	19712	19968	20224
80	20480	20736	20992	21248	21504	21760	22016	22272	22528	22734
90	23040	23296	23552	23808	24064	24320	24576	24832	25088	25344
100	25600	25856	26112	26368	26624	26880	27136	27392	27648	27904
110	28160	28416	28672	28928	29184	29440	29696	29952	30208	30464
120	30720	30976	31232	31488	31744	32000	32256	32512	32768	33024
130	33280	33536	33792	34048	34304	34560	34816	35072	35328	35584
140	35840	36096	36352	36608	36864	37120	37376	37632	37888	38144
150	38400	38656	38912	39168	39424	39680	39936	40192	40448	40704
160	40960	41216	41472	41728	41984	42240	42496	42752	43008	43264
170	43520	43776	44032	44288	44544	44800	45056	45312	45568	45824
180	46080	46336	46592	46848	47104	47360	47616	47872	48128	48384
190	48640	48896	49152	49408	49664	49920	50176	50432	50688	50944
200	51200	51456	51712	51968	52224	52480	52736	52992	53248	53504

DENSITIES OF COMMON METALS
(20 - 25°C)

Aluminum Al - 2.70
Antimony Sb - 6.685
Arsenic As - 5.7
Barium Ba - 3.5
Beryllium Be - 1.8
Bismuth Bi - 9.8
Cadmium Cd - 8.6
Calcium Ca - 1.55
Cerium Ce - 6.90
Cesium Cs - 1.9
Chromium Cr - 7.1
Cobalt Co - 8.9
Copper Cu - 8.93
Gallium Ga - 5.91
Germanium Ge - 5.36
Gold Au - 19.3
Indium In - 7.3
Iridium Ir - 22.4
Iron Fe - 7.86
Lanthanum La - 6.15
Lead Pb - 11.34
Lithium Li - 0.53
Magnesium Mg - 1.74
Manganese Mn - 7.2
Mercury Hg - 13.546 (liq.)
Molybdenum Mo - 10.2
Neodymium Nd - 6.9
Nickel Ni - 8.9
Osmium Os - 22.48
Palladium Pd - 12.1
Platinum Pt - 21.4
Potassium K - 0.86
Praseodymium Pr - 6.5
Rhenium Re - 21.4
Rhodium Rh - 12.5
Rubidium Rb - 1.53
Ruthenium Ru - 12.2
Selenium Se - 4.8
Silver Ag - 10.5
Sodium Na - 0.97
Strontium Sr - 2.6
Tantalum Ta - 16.6
Tellurium Te - 6.24
Thallium Tl - 11.85
Thorium Th - 11.4
Tin (White) Sn - 7.31
Tin (Grey) Sn - 5.75
Titanium Ti - 4.5
Uranium U - 18.9
Vanadium V - 5.96
Wolfram W - 19.3
Yttrium Y - 5.51
Zinc Zn - 7.14
Zirconium Zr - 6.4

DENSITY OF AIR

VARIOUS TEMPERATURES AND PRESSURES

TEMPERATURE °C	Pressure in Centimeters of Mercury				
	76	75	74	73	72
0	0.001293				
5	0.001270				
10	0.001247	0.001231	0.001215	0.001198	0.001182
11	0.001243	0.001227	0.001210	0.001193	0.001178
12	0.001239	0.001222	0.001206	0.001190	0.001173
13	0.001234	0.001218	0.001202	0.001186	0.001169
14	0.001230	0.001214	0.001198	0.001181	0.001165
15	0.001226	0.001210	0.001193	0.001177	0.001161
16	0.001221	0.001205	0.001189	0.001173	0.001157
17	0.001217	0.001201	0.001185	0.001169	0.001153
18	0.001213	0.001197	0.001181	0.001165	0.001149
19	0.001209	0.001193	0.001177	0.001161	0.001145
20	0.001205	0.001189	0.001173	0.001157	0.001141
21	0.001201	0.001185	0.001169	0.001153	0.001137
22	0.001197	0.001181	0.001165	0.001149	0.001134
23	0.001193	0.001177	0.001161	0.001145	0.001130
24	0.001189	0.001173	0.001157	0.001142	0.001126
25	0.001185	0.001169	0.001153	0.001138	0.001122
26	0.001181	0.001165	0.001149	0.001134	0.001118
27	0.001177	0.001161	0.001146	0.001130	0.001115
28	0.001173	0.001157	0.001142	0.001126	0.001111
29	0.001169	0.001153	0.001138	0.001123	0.001107
30	0.001165	0.001150	0.001134	0.001119	0.001104
35	0.001146				
40	0.001127				

THE ELECTROMAGNETIC SPECTRUM

Angstrom Unit - A physical unit of length, equal to $1/10^8$ centimeters.

Electron Volt - The amount of energy acquired by an electron falling through a potential difference of one volt.

Electron voltage (V) is related to the wavelength of radiation (λ), in Angstrom units, approximately thus: $V = 12420/\lambda$.

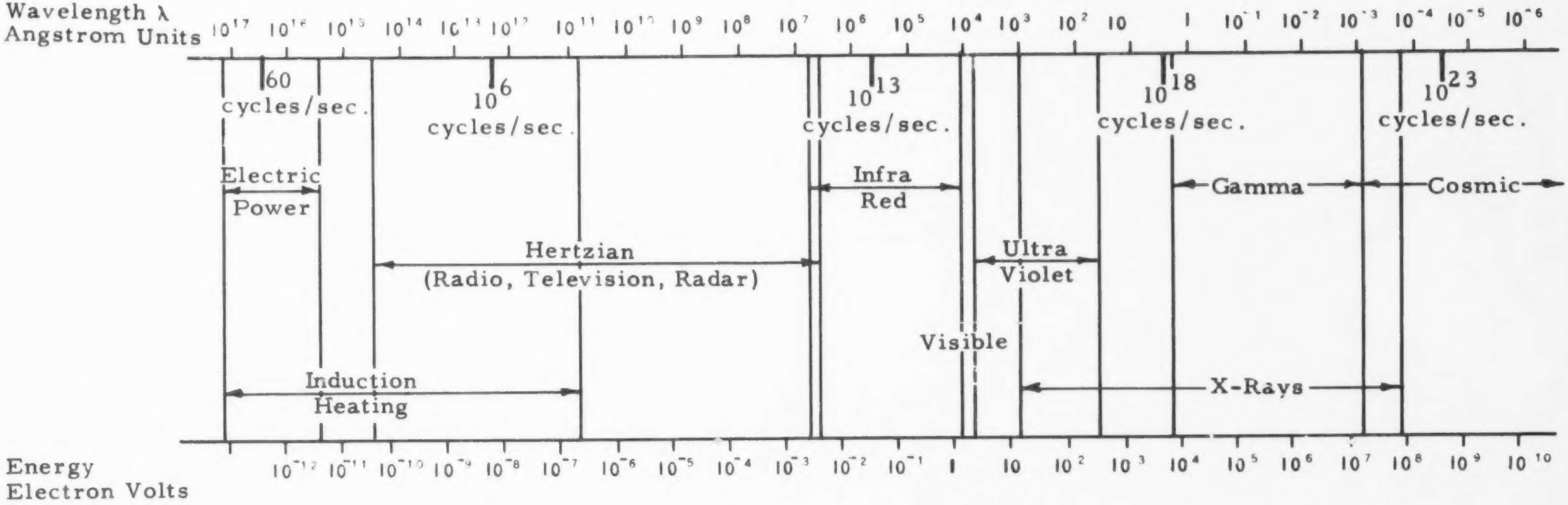
Wavelength and frequency are related by: $c = \lambda \nu$

c = velocity of electromagnetic waves
= 3×10^{10} centimeters per second

ν = frequency = cycles/sec. = vibrations per second

λ = wavelength in centimeters

Visible Spectrum Limits:
4,000 Angstroms – 8,000 Angstroms
7.5×10^{14} cycles/sec. - 3.7×10^{14} cycles/sec.


Wavelength λ
Angstrom Units
10^{17} 10^{16} 10^{15} 10^{14} 10^{13} 10^{12} 10^{11} 10^{10} 10^{9} 10^{8} 10^{7} 10^{6} 10^{5} 10^{4} 10^{3} 10^{2} 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6}
60 cycles/sec.
10^{6} cycles/sec.
10^{13} cycles/sec.
10^{18} cycles/sec.
10^{23} cycles/sec.
Electric Power
Infra Red
Gamma
Cosmic
Hertzian (Radio, Television, Radar)
Ultra Violet
Visible
Induction Heating
X-Rays
Energy
Electron Volts
10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10}

THE ELECTROMAGNETIC SPECTRUM

TYPE OF RADIATION	FREQUENCY RANGE (cycles/sec.)	WAVELENGTH RANGE (centimeters)	ENERGY (ergs)
Electric Waves	$0 - 10^{4}$	$\infty - 3 \times 10^{6}$	$0 - 10^{-22}$
Radio Waves	$10^{4} - 10^{11}$	$3 \times 10^{6} - 0.3$	$10^{-22} - 7 \times 10^{-15}$
Infra Red	$10^{11} - 3.7 \times 10^{14}$	$0.3 - 7.6 \times 10^{-5}$	$7 \times 10^{-15} - 3 \times 10^{-12}$
Visible	$3.7 \times 10^{14} - 7.5 \times 10^{14}$	$7.6 \times 10^{-5} - 4 \times 10^{-5}$	$3 \times 10^{-12} - 5 \times 10^{-12}$
Ultra Violet	$7.5 \times 10^{14} - 1 \times 10^{17}$	$4 \times 10^{-5} - 3 \times 10^{-7}$	$5 \times 10^{-12} - 7 \times 10^{-10}$
X-Rays	$3 \times 10^{15} - 3 \times 10^{22}$	$10^{-5} - 10^{-12}$	$2 \times 10^{-11} - 2 \times 10^{-4}$
Gamma Rays	$3 \times 10^{18} - 3 \times 10^{21}$	$10^{-8} - 10^{-11}$	$2 \times 10^{-8} - 2 \times 10^{-5}$
Cosmic Rays	3×10^{21} ----	10^{-11} ----	2×10^{-5} ----

ATOMIC MASSES IN MASS UNITS*

Physical Scale

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
-1	Electron	0	0.000548	8	Oxygen	15	15.007768
0	Neutron	1	1.008982			16	16.000000
1	Proton	1	1.007594			17	17.004533
1	Hydrogen	1	1.008142			18	18.004857
		2	2.014735			19	19.004456
		3	3.016997	9	Fluorine	17	17.007505
1	Deuteron	2	2.014187			18	18.006651
2	Alpha	4	4.002777			19	19.004456
2	Helium	3	3.016977			20	20.006352
		4	4.003873	10	Neon	19	19.007952
		5	5.015428			20	19.998777
		6	6.020833			21	19.000504
3	Lithium	6	6.017021			22	21.998358
		7	7.018223			23	23.001768
		8	8.025018	11	Sodium	21	21.004286
4	Beryllium	7	7.019150			22	22.001409
		8	8.007850			23	22.997055
		9	9.015043			24	23.998568
		10	10.016711	12	Magnesium	23	23.001453
5	Boron	9	9.016190			24	23.992628
		10	10.016114			25	24.993745
		11	11.012789			26	25.990802
		12	12.018162			27	26.992876
6	Carbon	10	10.02086	13	Aluminum	26	25.99443
		11	11.014916			27	26.990071
		12	12.003804			28	27.990760
		13	13.007473			29	28.9892
		14	14.007682	14	Silicon	28	27.985767
7	Nitrogen	13	13.009858			29	28.985650
		14	14.007515			30	29.983237
		15	15.004863			31	30.985140
		16	16.00645	15	Phosphorus	29	28.99151

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
15	**Phosphorus**	30	29.9885	22	Titanium	48	47.96317
		31	30.983550			49	48.96358
		32	31.984016			50	49.96077
		33	32.982166			51	50.9587
16	**Sulfur**	31	30.98965	23	Vanadium	50	49.96040
		32	31.982183			51	50.96052
		33	32.981881			52	51.95741
		34	33.97876	24	Chromium	50	49.96020
		35	34.9788			51	50.958
		36	35.978			52	51.95710
17	Chlorine	33	32.9860			53	52.95772
		34	33.9801			54	53.9563
		35	34.98004	25	Manganese	54	53.95664
		36	35.97803			55	54.95581
		37	36.97770	26	Iron	54	53.95664
		38	37.97999			56	55.85272
18	Argon	35	34.9850			57	56.95359
		36	35.97900			58	57.9520
		38	37.97491	27	Cobalt	59	58.95029
		40	39.97513	28	Nickel	58	57.95354
		41	40.97740			60	59.94981
19	Potassium	38	37.9795			61	60.9540
		39	38.97606			62	61.94959
		40	39.9760			64	63.94744
		41	40.97490	29	Copper	63	62.957
20	Calcium	40	39.97545			64	63.955
		42	41.97216			65	64.94884
		43	42.97251	30	Zinc	64	63.957
		44	43.96924			65	64.95654
		45	44.97075			66	65.953
		48	47.96778			67	66.954
21	Scandium	45	44.97000			68	67.955
		46	45.96909			70	69.954
22	Titanium	46	45.96697	31	Gallium	69	68.956
		47	46.96668			71	70.954

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
32	Germanium	74		46	Palladium	105	104.942
33	Arsenic	75	74.934			106	105.946
34	Selenium	78	77.938			108	107.93682
		80	79.942			110	109.94060
35	Bromine	79	78.944	47	Silver	107	106.950
		81	80.943			108	107.947
36	Krypton	78	77.945			109	108.949
		81	81.938	48	Cadmium	110	109.93873
		82	82.939			112	111.93997
		84	83.939			116	115.94200
		86	85.939	49	Indium	113	
37	Rubidium	85	84.931			115	
		87	86.9295	50	Tin	115	114.940
38	Strontium	86	85.93533			116	115.93852
		88	87.93374			117	116.94208
39	Yttrium	89				118	117.940
40	Zirconium	90	89.93178			119	118.938
41	Columbium	93	92.926			120	119.94012
42	Molybdenum	94	93.945			122	121.946
		95	94.945			124	123.945
		96	95.93597	51	Antimony	121	
		97	96.945			123	
		98	97.93610	52	Tellurium	126	125.937
		100	99.93860			127	126.936
43	Technetium			53	Iodine	127	126.933
44	Ruthenium	96	95.945	54	Xenon	129	128.9455
		98	97.943			130	129.945
		99	98.944			131	130.944
		100	99.942			132	132.945
		101	100.946			134	133.947
		102	101.941	55	Cesium		
45	Rhodium	103	102.949	56	Barium	138	137.916
46	Palladium	102	101.941	57	Lanthanum	139	138.953
		104	103.93635	58	Cerium	136	

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
58	Cerium	138		68	Erbium	167	
		140				168	
		142				170	
59	Praseodymium	141		69	Thulium	169	
60	Neodymium	145	144.962	70	Ytterbium	168	
		146	145.964			170	
		148	147.964			171	
		150	149.970			172	
61	Prometheum	147				173	
62	Samarium	144				174	
		147				176	
		149		71	Lutecium	175	
		150		72	Hafnium	174	
		152				176	
		154				177	
63	Europium	151				178	
		153				179	
64	Gadolinium	154	153.971			180	
		155	154.977	73	Tantalum	181	180.928
		156	155.977	74	Tungsten	184	184.00
		157	156.976	75	Rhenium	187	186.981
		158	157.976	76	Osmium	189	189.04
		160	159.976			190	190.038
65	Terbium	159				192	192.038
66	Dysprosium	158		77	Iridium	191	191.038
		160				193	193.039
		161		78	Platinum	194	194.0256
		162				195	195.02652
		163				196	196.02744
		164				198	198.044
67	Holmium	165	164.98	79	Gold	197	197.039
68	Erbium	162		80	Mercury	200	200.028
		164		81	Thallium	203	203.03481
		166				204	204.03677

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
81	Thallium	205	205.03761	85	Astatine	218	218.07609
		206	206.03990	86	Radon	212	212.05614
		207	207.01459			215	215.06533
		208	208.04647			216	216.06722
		209	209.05014			217	217.07127
		210	210.05507			218	218.07323
82	Lead	204	204.03594			219	219.07749
		206	206.03828			220	220.07965
		207	207.04004			222	222.08638
		208	208.04110	87	Francium	218	218.07516
		209	209.04593			219	219.07720
		210	210.04929			220	220.08058
		211	211.05421			221	221.08274
		212	212.05762			223	223.08889
		214	214.06607	88	Radium	219	219.07796
83	Bismuth	209	209.04524			220	220.07922
		210	210.04921			221	221.08248
		211	211.05271			222	222.08422
		212	212.05700			223	223.08765
		213	213.06042			224	224.08973
		214	214.06497			225	225.09330
84	Polonium	208	208.04541			226	226.09547
		210	210.04795			227	227.09956
		211	211.05205			228	228.10199
		212	212.05458	89	Actinium	222	222.08665
		213	213.05893			223	223.08833
		214	214.06157			224	224.09120
		215	215.06615			225	225.09295
		216	216.06891			226	226.09624
		218	218.07650			227	227.09816
85	Astatine	214	214.02629			228	228.10194
		215	215.06533	90	Thorium	223	223.09009
		216	216.06940			224	224.09090
		217	217.07197			225	225.09354

Z No.	Element	A No.	Mass(mu)	Z No.	Element	A No.	Mass(mu)
90	Thorium	226	226.09498	93	Neptunium	235	235.11695
		227	227.09812			236	236.11991
		228	228.09953			237	237.12158
		229	229.10267			238	238.12494
		230	230.10447			239	239.12704
		231	231.10789			240	240.13083
		232	232.11021	94	Plutonium	232	232.11313
		233	233.11370			234	234.11588
		234	234.11625			235	235.11822
91	Protoactinium	226	226.09796			236	236.11936
		227	227.09927			238	238.12342
		228	228.10173			239	239.12627
		229	229.10304			240	240.12851
		231	231.10755			241	241.13153
		232	232.11086			242	242.13389
		233	233.11238			243	243.13734
		234	234.11562	95	Americium	237	237.12339
		235	235.11827			239	239.12710
92	Uranium	227	227.10163			241	241.13151
		228	228.10206			242	242.13467
		229	229.10443			243	243.13674
		230	230.10524	96	Curium	238	238.12685
		231	231.10796			240	240.13008
		232	232.10921			242	242.13397
		233	233.11181			243	243.13675
		234	234.11355			244	244.13872
		235	235.11677	97	Berkelium	243	243.13831
		236	236.11900			245	245.14230
		237	237.12213	98	Californium	244	244.14176
		238	238.12469			246	246.14521
		239	239.12844				
		240	240.13122				
93	Neptunium	231	231.11001				
		233	233.11296				

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Periodic Table

IA	II A	III A	IV B	V B	VI B	VII B	VIII	
1 H 1.0080								
3 Li 6.940	4 Be 9.013	5 B 10.82						
11 Na 22.997	12 Mg 24.32	13 Al 26.98						
19 K 39.100	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.93	26 Fe 55.85	27 Co 58.94
37 Rb 85.48	38 Sr 87.63	39 Y 88.92	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (99)	44 Ru 101.7	45 Rh 102.91
55 Cs 132.91	56 Ba 137.36	57 La 138.92	72 Hf 178.6	73 Ta 180.88	74 W 183.92	75 Re 186.31	76 Os 190.2	77 Ir 193.1
87 Fr (223)	88 Ra 226.05	89 Ac 227						

Lanthanide Series	58 Ce 140.13	59 Pr 140.92	60 Nd 144.27	61 Pm (145)	62 Sm 150.43
Actinide Series	90 Th 232.12	91 Pa 231	92 U 238.07	93 Np (237)	94 Pu (242)

Key

Atomic Symbol

Atomic Number

# of the Elements

	IB	IIB	IIIB	IVA	VA	VIA	VIIA	INERT GASES
								4.003 **He** 2 Helium
				12.010 **C** 6 Carbon	14.008 **N** 7 Nitrogen	16 **O** 8 Oxygen	19.00 **F** 9 Fluorine	20.183 **Ne** 10 Neon
				28.09 **Si** 14 Silicon	30.975 **P** 15 Phosphorus	32.066 **S** 16 Sulfur	35.457 **Cl** 17 Chlorine	39.944 **A** 18 Argon
58.69 **Ni** 28 Nickel	63.54 **Cu** 29 Copper	65.38 **Zn** 30 Zinc	69.72 **Ga** 31 Gallium	72.60 **Ge** 32 Germanium	74.91 **As** 33 Arsenic	78.96 **Se** 34 Selenium	79.916 **Br** 35 Bromine	83.80 **Kr** 36 Krypton
106.7 **Pd** 46 Palladium	107.880 **Ag** 47 Silver	112.41 **Cd** 48 Cadmium	114.76 **In** 49 Indium	118.70 **Sn** 50 Tin	121.76 **Sb** 51 Antimony	127.61 **Te** 52 Tellurium	126.91 **I** 53 Iodine	131.3 **Xe** 54 Xenon
195.23 **Pt** 78 Platinum	197.2 **Au** 79 Gold	200.61 **Hg** 80 Mercury	204.39 **Tl** 81 Thallium	207.21 **Pb** 82 Lead	209.00 **Bi** 83 Bismuth	210 **Po** 84 Polonium	(210) **At** 85 Astatine	222 **Rn** 86 Radon

152.0 **Eu** 63 Europium	156.9 **Gd** 64 Gadolinium	159.2 **Tb** 65 Terbium	162.46 **Dy** 66 Dysprosium	164.94 **Ho** 67 Holmium	167.2 **Er** 68 Erbium	169.4 **Tm** 69 Thulium	173.04 **Yb** 70 Ytterbium	174.99 **Lu** 71 Lutetium
(243) **Am** 95 Americium	(243) **Cm** 96 Curium	(245) **Bk** 97 Berkelium	(246) **Cf** 98 Californium	99	100	101	102	103

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SECTION III

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ISOTOPES AVAILABLE IN THE UNITED STATES AND CANADA LISTED BY INCREASING HALF-LIFE

Half-Life	Element & Symbol	Atomic Number	Mass Number	Radiation Energy (Mev) Beta	Gamma
30s	Rhodium(Rh)	45	106	3.53, 3.1, 2.44, 2.0	.513,.624,.87. 1.045,1.55,2.41
2.6m	Barium(Ba)	56	137m	IT	.66
17.5m	Praseodymium(Pr)	59	144	2.97	.06,.696,1.5,2.19
53.93m	Indium(In)	49	116m	1.0,.87,.60	2.09,1.49,1.27 1.09,.41,.137
2.576h	Manganese(Mn)	25	56	2.81,1.04,.65	.822,1.77,2.06
2.62h	Silicon(Si)	14	31	1.471	.17,.52
4.5h	Ruthenium(Ru)	44	105	1.15	.726
9.2h	Europium(Eu)	63	152	1.88,.55	.122,.344
9.3h	Tellurium(Te)	52	127	0.7	none
12.44h	Potassium(K)	19	42	3.58,2.04	1.51
12.80h	Copper(Cu)	29	64	0.57(β^-) 0.657(β^+)	1.34
13.6h	Palladium(Pd)	46	109	0.96	none
13.8h	Zinc(Zn)	30	69m	IT	.437
14.3h	Gallium(Ga)	31	72	3.15,2.52,1.5, .9,.6	2.49,2.51
15.06h	Sodium(Na)	11	24	1.39	1.37,2.75
16.9h	Rhenium(Re)	75	188	2.07	.155,.476,.638, .933,1.3
17.0h	Zirconium(Zr)	40	97	1.91	none
18h	Platinum(Pt)	78	197	.67	.077,.191
19.0h	Iridium(Ir)	77	194	2.18	.290,.326,1.51
19.2h	Praseodymium(Pr)	59	142	2.15,.64	.135,1.59
23h	Mercury(Hg)	80	$197m_2$	EC IT	.191 .133
24.1h	Wolfram(W) (Tungsten)	74	187	1.33,.63	.072,.13,.48, .62,.68
26.8h	Arsenic(As)	33	76	3.04,2.49,1.29	.55,1.20,1.70
27.3h	Holmium(Ho)	67	166	1.84,.55	.08,1.38
27.5h	Tin(Sn)	50	121	.383	none
30.6h	Osmium(Os)	76	193	1.10	none
35.87h	Bromine(Br)	35	82	.465	.547,.608,.692, .766,.823,1.03, 1.31
36.5h	Rhodium(Rh)	45	105	.57,.25	.322,.157,.08
38h	Arsenic(As)	33	77	.70	none
40.0h	Lanthanum(La)	57	140	1.32,1.67,2.26	.093,.33,.49,.81, 1.6,2.5,3.0
47h	Samarium(Sm)	62	153	.80,.70	.07,.10,.53,.60
53h	Cadmium	48	115	1.11,.58	.36,.5,.52
54h	Promethium(Pm)	61	149	1.05	.29,1.3
61h	Yttrium(Y)	39	90	2.18	none
2.69d	Gold(Au)	79	198	.963	.41,.68,1.1
2.708d	Mercury(Hg)	80	197	EC	.08,.19
2.792d	Molybdenum(Mo)	42	99	1.23,.45	.04,.18,.37,.74, .78
2.80d	Antimony(Sb)	51	122	1.94,1.36	.57

ISOTOPES AVAILABLE IN THE UNITED STATES AND CANADA LISTED BY INCREASING HALF-LIFE

Half-Life	Element & Symbol	Atomic Number	Mass Number	Radiation Energy (Mev) Beta	Gamma
2.8d	Ruthenium(Ru)	44	97	EC	.217
3.15d	Gold(Au)	79	199	.46,.30,.25	.05,.16,.21
3.87d	Rhenium(Re)	75	186	1.07,.93	.137,.123
5.02d	Bismuth(Bi)	83	210	1.17	none
6.0d	Manganese(Mn)	25	52	EC(β^+ = .6)	.73,.94,1.46
7.6d	Silver(Ag)	47	111	1.04,.8,.7	.24,.34
8.141d	Iodine(I)	53	131	.81,.61,.34,.25	.08,.16,.28,.36, .64,.72
9.6d	Cesium(Cs)	55	131	EC	
11.3d	Neodymium(Nd)	60	147	.83,.60,.38	.09,.31,.39,.52
11.4d	Germanium(Ge)	32	71	EC	
12.0d	Barium(Ba)	56	131	EC	.12,.20,.21,.24, .37,.49
12.0d	Xenon(Xe)	54	$131m_2$	IT	.163
12.80d	Barium(Ba)	56	140	1.02,.48	.03,.13,.16,.30, .54
[illegible]	Praseodymium(Pr)	59	143	.932	none
[illegible]	Phosphorus(P)	15	32	1.70	none
16.0d	Osmium(Os)	76	191	.143	.04,.129
17.0d	Palladium(Pd)	46	103	EC	
17.5d	Arsenic(As)	33	74	1.36,.69 (β^+ = 1.53,.92)	.596,.635
19.5d	Rubidium(Rb)	37	86	1.82,.72	1.076
27.8d	Chromium(Cr)	24	51	EC	.33
33.1d	Cerium(Ce)	58	141	.58,.44	.145
33.5d	Tellurium(Te)	52	129m	IT	.106
35.0d	Argon(A)	18	37	EC	
35d	Niobium(Nb)	41	95	.16	.745
39.8d	Ruthenium(Ru)	44	103	.217,.698	.498
43d	Cadmium(Cd)	48	115m	1.61,.7,.3	.46,.50,.96, 1.28
45d	Hafnium(Hf)	72	181	.408	.133,.136,.34,.48, .61
45.1d	Iron(Fe)	26	59	.46,.26	1.295,1.097
47.9d	Mercury(Hg)	80	203	.208	.279
49d	Indium(In)	49	114m	IT	.19
52.93d	Beryllium(Be)	4	7	EC	.479
53d	Strontium(Sr)	38	89	1.463	none
60d	Antimony(Sb)	51	124	2.29,1.69,.95, .68,.50	.12,.61,.65,.73, 1.71,2.04
65d	Zirconium(Zr)	40	95	.371,.84	.721
72d	Cobalt(Co)	27	58	EC,(β^+ = .47)	.81
73.2d	Wolfram(W) (Tungsten)	74	185	.428	.134
74.37d	Iridium(Ir)	77	192	.66	.13,.20,.21,.29, .31,.32,.47,.48, .59,.60,.61
76d	Arsenic(As)	33	73	EC	.013
85d	Scandium(Sc)	21	46	.36	.89,1.12

ISOTOPES AVAILABLE IN THE UNITED STATES AND CANADA LISTED BY INCREASING HALF-LIFE

Half-Life	Element & Symbol	Atomic Number	Mass Number	Radiation Energy (Mev)	
				Beta	Gamma
87.1d	Sulfur(S)	16	35	.167	none
90d	Technetium(Tc)	43	97m	IT	.096
97d	Osmium(Os)	76	185	EC	.648,.878
111d	Tantalum(Ta)	73	182	.525	.07,.10,.15,.22, 1.12,1.19,1.22
112d	Tin(Sn)	50	113	EC	none
115d	Tellurium(Te)	52	127m	IT	.088
127d	Selenium(Se)	34	75	EC	.07,.10,.27,.28, .35,.41
138.3d	Polonium(Po)	84	210	(α = 5.298)	.80
152d	Calcium(Ca)	20	45	.254	none
250d	Zinc(Zn)	30	65	EC (β^+ = .325)	1.12
270d	Cobalt(Co)	27	57	(β^+ = .26)	.12,.13
270d	Silver(Ag)	47	110m	.09,.53,2.12, 2.86	.12,.66,.68,.71, .76,.81,.89,.94, 1.39,1.52
282d	Cerium(Ce)	58	144	.30,.17	.034,.054,.081, .134
310d	Manganese(Mn)	25	54	EC	.84
1.0y	Ruthenium(Ru)	44	106	.039	none
1.7y	Europium(Eu)	63	155	.154,.243	.06,.09,.11,.132
2.3y	Cesium(Cs)	55	134	.65,.09	.56,.57,.60,.79, 1.04,1.16,1.36
2.6y	Promethium(Pm)	61	147	.223	none
2.6y	Sodium(Na)	11	22	(β^+ = .542,1.8)	1.277
2.7y	Antimony(Sb)	51	125	.62,.30,.13	.64,.47,.18,.04
2.94y	Iron(Fe)	26	55	EC	none
3.5y	Thallium(Tl)	81	204	.765	none
5.27y	Cobalt(Co)	27	60	.306	1.33,1.17
12.46y	Hydrogen(H)	1	3	.018	none
13y	Europium(Eu)	63	152	1.58, EC	.12,.24,.34,.72, .96,1.09
16y	Europium(Eu)	63	154	1.9,.7,.3	.34,.78,1.12
19.9y	Strontium(Sr)	38	90	.61	none
22.0y	Actinium(Ac)	89	227	.04(α = 4.94)	.037
22.0y	Lead(Pb)	82	210	.018	.0467
33y	Cesium(Cs)	55	137	.523,1.17	.661
85y	Nickel(Ni)	28	63	.067	none
1622y	Radium(Ra)	88	226	(α= 4.777)	.186
5568y	Carbon(C)	6	14	.155	none
8 x 10^4y	Nickel(Ni)	28	59	EC	none
2.12x10^5y	Technetium(Tc)	43	99	.29	none
4.4 x10^5y	Chlorine(Cl)	17	36	.714	none

ACTIVITY MASS RELATIONSHIP - SPECIFIC ACTIVITY

$$\text{Specific Activity (Sp A) in dis/sec/gm} = \frac{0.693\ N}{T_{\frac{1}{2}}}$$

N = number of radioactive atoms per gram and
$T_{\frac{1}{2}}$ is the half-life expressed in seconds.

In calculating specific activity it is more convenient to use a variation of the basic equation, which is transformed as follows:

By def: $N = \text{Avogadro's number/atomic weight} = \dfrac{6.03 \times 10^{23}}{\text{atomic weight}}$

By def: $\text{dis/sec}/3.7 \times 10^{10} = \text{curies}$

Substituting:

$$\text{Sp A} = \frac{.693\ N}{T_{\frac{1}{2}}\ \text{(in secs)}} = \frac{.693}{T_{\frac{1}{2}}} \times \frac{6.03 \times 10^{23}}{\text{atomic weight}} \times \frac{1}{3.7 \times 10^{10}} = \text{c/gm}$$

This equation is satisfactory when the half-life of the nuclide whose specific activity is needed is expressed in seconds. If, however, the half-life is expressed in other units such as minutes, hours, days, or years, a separate time conversion is required for each. By substituting the appropriate time conversion factors as listed in the table of Conversion Factors in this Handbook the following five equations can be obtained.

$$\text{(1) Curies/gram or Sp A } (T_{\frac{1}{2}} \text{ in secs}) = \frac{1.13 \times 10^{13}}{(T_{\frac{1}{2}})\ (\text{atomic weight})}$$

$$\text{(2) Curies/gram or Sp A } (T_{\frac{1}{2}} \text{ in mins}) = \frac{1.884 \times 10^{11}}{(T_{\frac{1}{2}})\ (\text{atomic weight})}$$

$$\text{(3) Curies/gram or Sp A } (T_{\frac{1}{2}} \text{ in hrs}) = \frac{3.14 \times 10^{9}}{(T_{\frac{1}{2}})\ (\text{atomic weight})}$$

$$\text{(4) Curies/gram or Sp A } (T_{\frac{1}{2}} \text{ in days}) = \frac{1.308 \times 10^{8}}{(T_{\frac{1}{2}})\ (\text{atomic weight})}$$

$$\text{(5) Curies/gram or Sp A } (T_{\frac{1}{2}} \text{ in yrs}) = \frac{3.59 \times 10^{5}}{(T_{\frac{1}{2}})\ (\text{atomic weight})}$$

In making a calculation choose the appropriate equation as illustrated in the following example. Calculate the Sp A for Na^{22} whose half-life is 2.6 years. Choose equation (5) above, use the mass number as the atomic weight, and make the appropriate substitutions.

$$\text{Sp A} = \frac{3.59 \times 10^{5}}{T_{\frac{1}{2}}\ \text{(years)} \times \text{atomic wt}} = \frac{3.59 \times 10^{5}}{2.6 \times 22} = \overset{6.28}{\cancel{\text{[illegible]}}} \times 10^{3}\ \text{curies/gm}$$

The entry in the following table under the heading "grams per curie" is the reciprocal of Specific Activity in curies per gram and in this case $\dfrac{1}{\underset{6.28}{\cancel{\text{[illegible]}}} \times 10^{3}} = 1.59 \times 10^{-4}$ grams per curie.

The values in the tables on the succeeding pages were calculated from equations (1), (2), (3), (4), and (5) above.

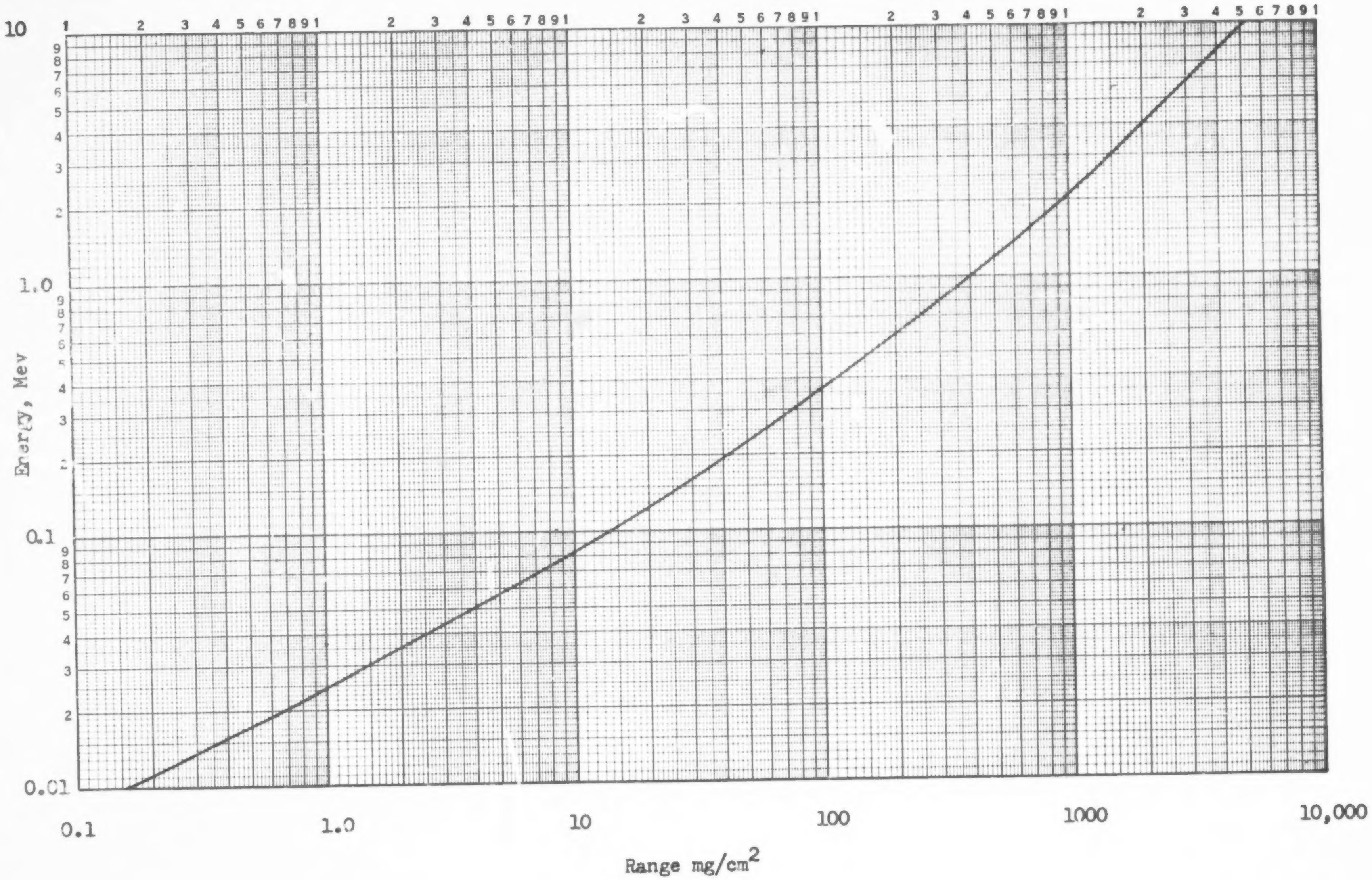
ACTIVITY MASS RELATIONSHIP - SPECIFIC ACTIVITY

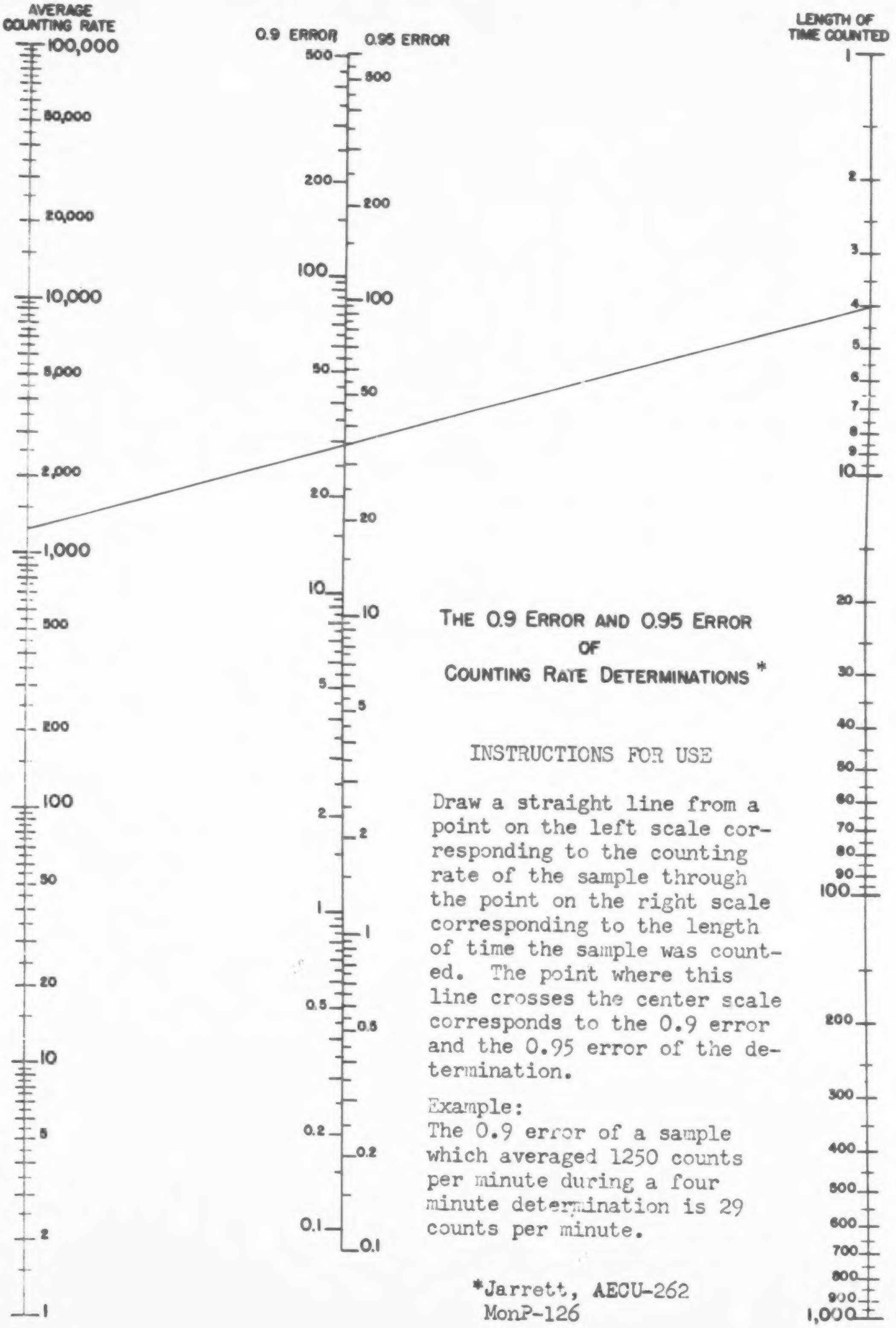
ISOTOPE	HALF LIFE		CURIES PER GRAM	GRAMS PER CURIE
Th-232	1.39×10^{10}	years	1.11×10^{-7}	9.0×10^{6}
U-238	4.49×10^{9}	y	3.36×10^{-7}	2.98×10^{6}
U-235	7.13×10^{8}	y	2.14×10^{-6}	4.67×10^{5}
Cl-36	4.4×10^{5}	y	2.27×10^{-2}	44.1
U-233	1.62×10^{5}	y	9.51×10^{-3}	1.05×10^{2}
Ni-59	8×10^{4}	y	7.61×10^{-2}	13.1
Pu-239	2.436×10^{4}	y	6.17×10^{-2}	16.2
C-14	5568	y	4.61	0.22
Ra-226	1622	y	0.98 or 1	1.02
Cs-137	33	y	79.4	1.26×10^{-2}
Sr-90	19.9	y	2.00×10^{2}	4.99×10^{-3}
H-3	12.46	y	9.60×10^{3}	1.04×10^{-4}
Co-60	5.27	y	1.14×10^{3}	8.81×10^{-4}
Tl-204	3.5	y	5.03×10^{2}	1.99×10^{-3}
Fe-55	2.94	y	2.22×10^{3}	4.50×10^{-4}
Pm-147	2.6	y	9.39×10^{2}	1.07×10^{-3}
Cs-134	2.3	y	1.16×10^{3}	8.62×10^{-4}
Ru-106	1.0	y	3.39×10^{3}	2.95×10^{-4}
Ce-144	282	days	3.22×10^{3}	3.10×10^{-4}
Zr-65	250	d	8.05×10^{3}	1.24×10^{-4}
Ca-45	152	d	1.91×10^{4}	5.23×10^{-5}
Po-210	138.3	d	4.50×10^{3}	2.22×10^{-4}
Ta-182	111	d	6.47×10^{3}	1.54×10^{-4}
S-35	87.1	d	4.28×10^{4}	2.34×10^{-5}
W-185	73.2	d	9.66×10^{3}	1.04×10^{-4}

ACTIVITY MASS RELATIONSHIP - SPECIFIC ACTIVITY

ISOTOPE	HALF LIFE		CURIES PER GRAM	GRAMS PER CURIE
Y-91	61	days	2.36×10^{4}	4.24×10^{-5}
Sr-89	53	d	2.77×10^{4}	3.61×10^{-5}
Fe-59	45.1	d	4.92×10^{4}	2.03×10^{-5}
Cr-51	27.8	d	9.23×10^{4}	1.08×10^{-5}
Th-234	24.1	d	2.32×10^{4}	4.31×10^{-5}
Rb-86	19.5	d	7.80×10^{4}	1.28×10^{-5}
P-32	14.3	d	2.85×10^{5}	3.5×10^{-6}
Ba-140	12.8	d	7.30×10^{4}	1.37×10^{-5}
I-131	8.14	d	1.23×10^{5}	8.15×10^{-6}
Au-199	3.15	d	2.09×10^{5}	4.79×10^{-6}
Au-198	2.7	d	2.44×10^{5}	4.1×10^{-6}
Mo-99	67	hours	4.73×10^{5}	2.11×10^{-6}
Y-90	61	h	5.72×10^{5}	1.75×10^{-6}
La-140	40	h	5.61×10^{5}	1.78×10^{-6}
Br-82	35.87	h	1.07×10^{6}	9.37×10^{-7}
As-76	26.8	h	1.54×10^{6}	6.48×10^{-7}
Na-24	15.06	h	8.69×10^{6}	1.15×10^{-7}
Ga-72	14.3	h	3.04×10^{6}	3.29×10^{-7}
Cu-64	12.8	h	3.83×10^{6}	2.61×10^{-7}
K-42	12.44	h	6.01×10^{6}	1.66×10^{-7}
Mn-56	2.576	h	2.18×10^{7}	4.59×10^{-8}
A-41	109	minutes	4.22×10^{7}	2.37×10^{-8}
Pr-144	17.5	m	7.48×10^{7}	1.34×10^{-8}
N-16	7.35	seconds	9.6×10^{10}	1.04×10^{-11}
Po-212	3×10^{-7}	s	1.8×10^{17}	5.6×10^{-18}

BETA PARTICLE
RANGE ENERGY CURVE





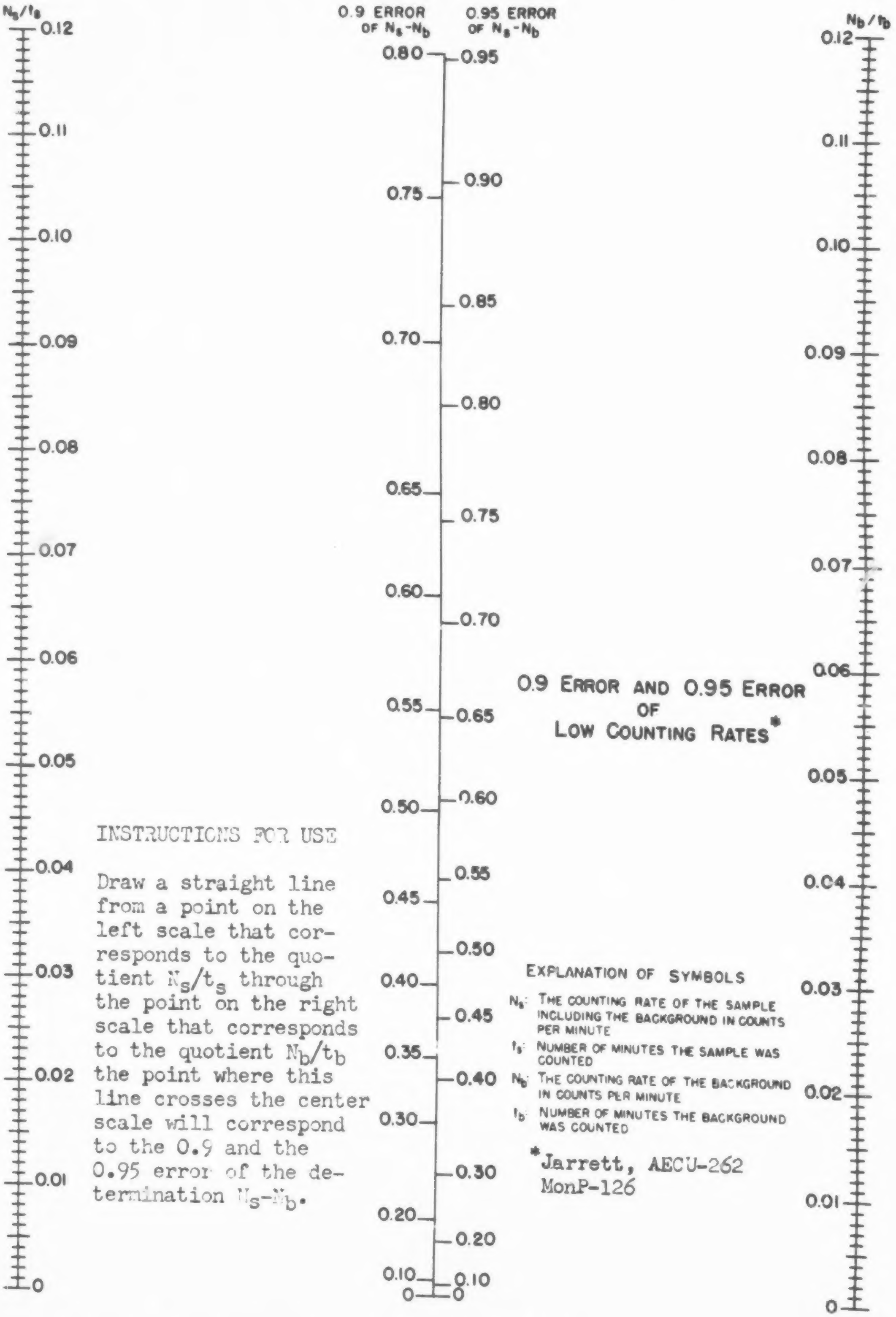
THE 0.9 ERROR AND 0.95 ERROR OF COUNTING RATE DETERMINATIONS *

INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale corresponding to the counting rate of the sample through the point on the right scale corresponding to the length of time the sample was counted. The point where this line crosses the center scale corresponds to the 0.9 error and the 0.95 error of the determination.

Example:
The 0.9 error of a sample which averaged 1250 counts per minute during a four minute determination is 29 counts per minute.

*Jarrett, AECU-262
MonP-126



0.9 ERROR AND 0.95 ERROR OF LOW COUNTING RATES*

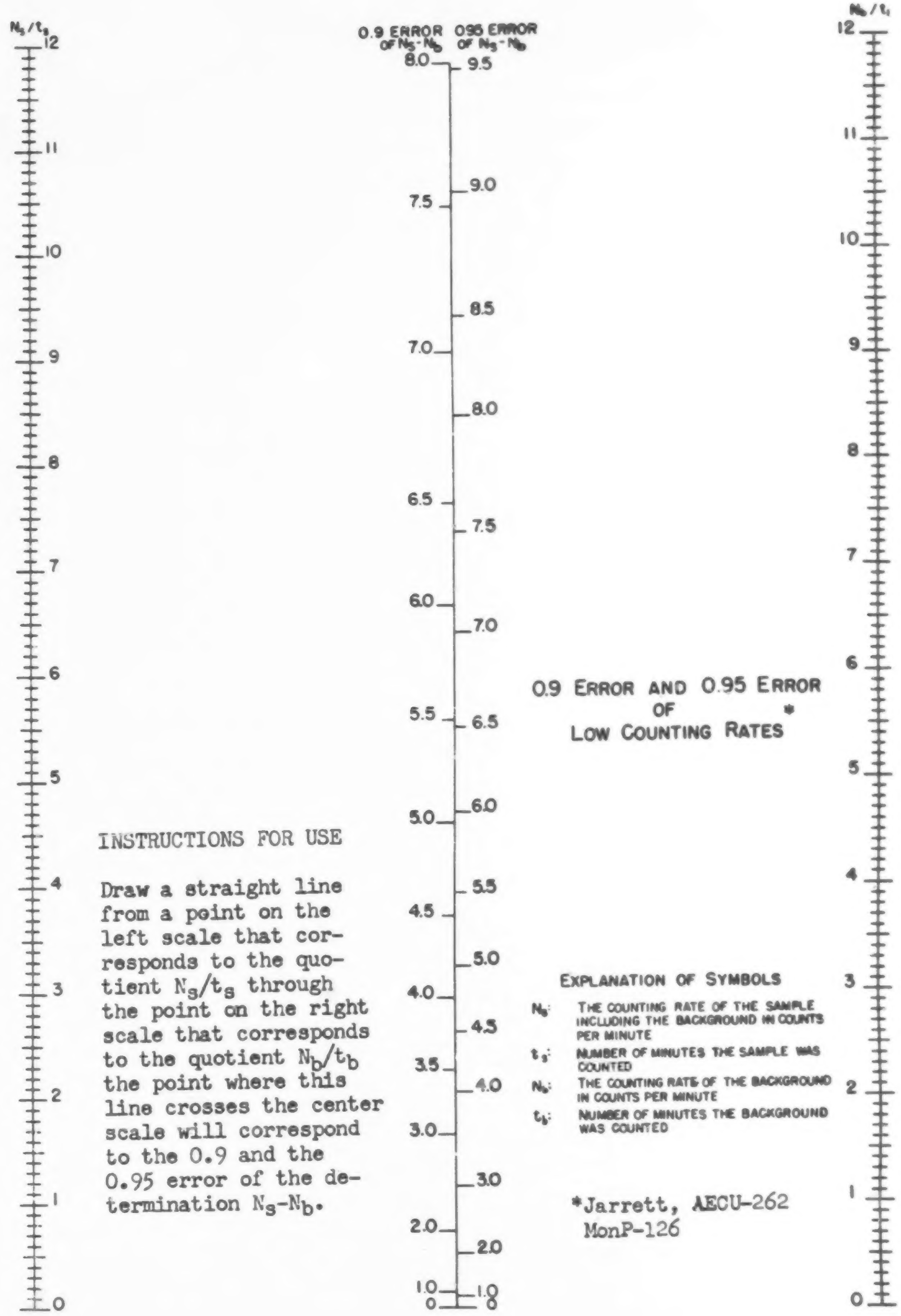
INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale that corresponds to the quotient N_s/t_s through the point on the right scale that corresponds to the quotient N_b/t_b the point where this line crosses the center scale will correspond to the 0.9 and the 0.95 error of the determination N_s-N_b.

EXPLANATION OF SYMBOLS

N_s:	THE COUNTING RATE OF THE SAMPLE INCLUDING THE BACKGROUND IN COUNTS PER MINUTE
t_s:	NUMBER OF MINUTES THE SAMPLE WAS COUNTED
N_b:	THE COUNTING RATE OF THE BACKGROUND IN COUNTS PER MINUTE
t_b:	NUMBER OF MINUTES THE BACKGROUND WAS COUNTED

*Jarrett, AECU-262
MonP-126



0.9 ERROR AND 0.95 ERROR OF LOW COUNTING RATES*

INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale that corresponds to the quotient N_s/t_s through the point on the right scale that corresponds to the quotient N_b/t_b the point where this line crosses the center scale will correspond to the 0.9 and the 0.95 error of the determination N_s-N_b.

EXPLANATION OF SYMBOLS

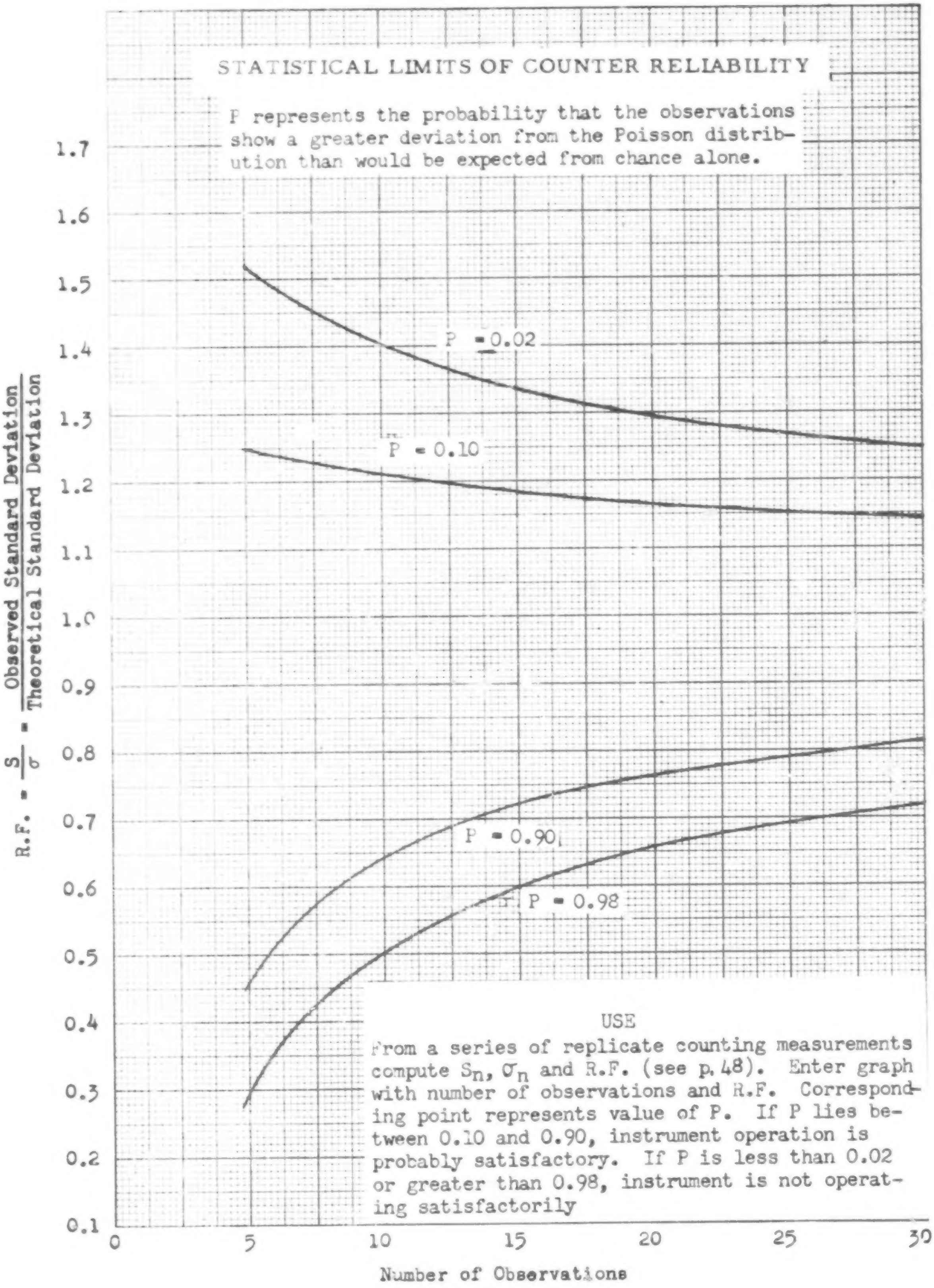
N_s: THE COUNTING RATE OF THE SAMPLE INCLUDING THE BACKGROUND IN COUNTS PER MINUTE

t_s: NUMBER OF MINUTES THE SAMPLE WAS COUNTED

N_b: THE COUNTING RATE OF THE BACKGROUND IN COUNTS PER MINUTE

t_b: NUMBER OF MINUTES THE BACKGROUND WAS COUNTED

*Jarrett, AECU-262
MonP-126

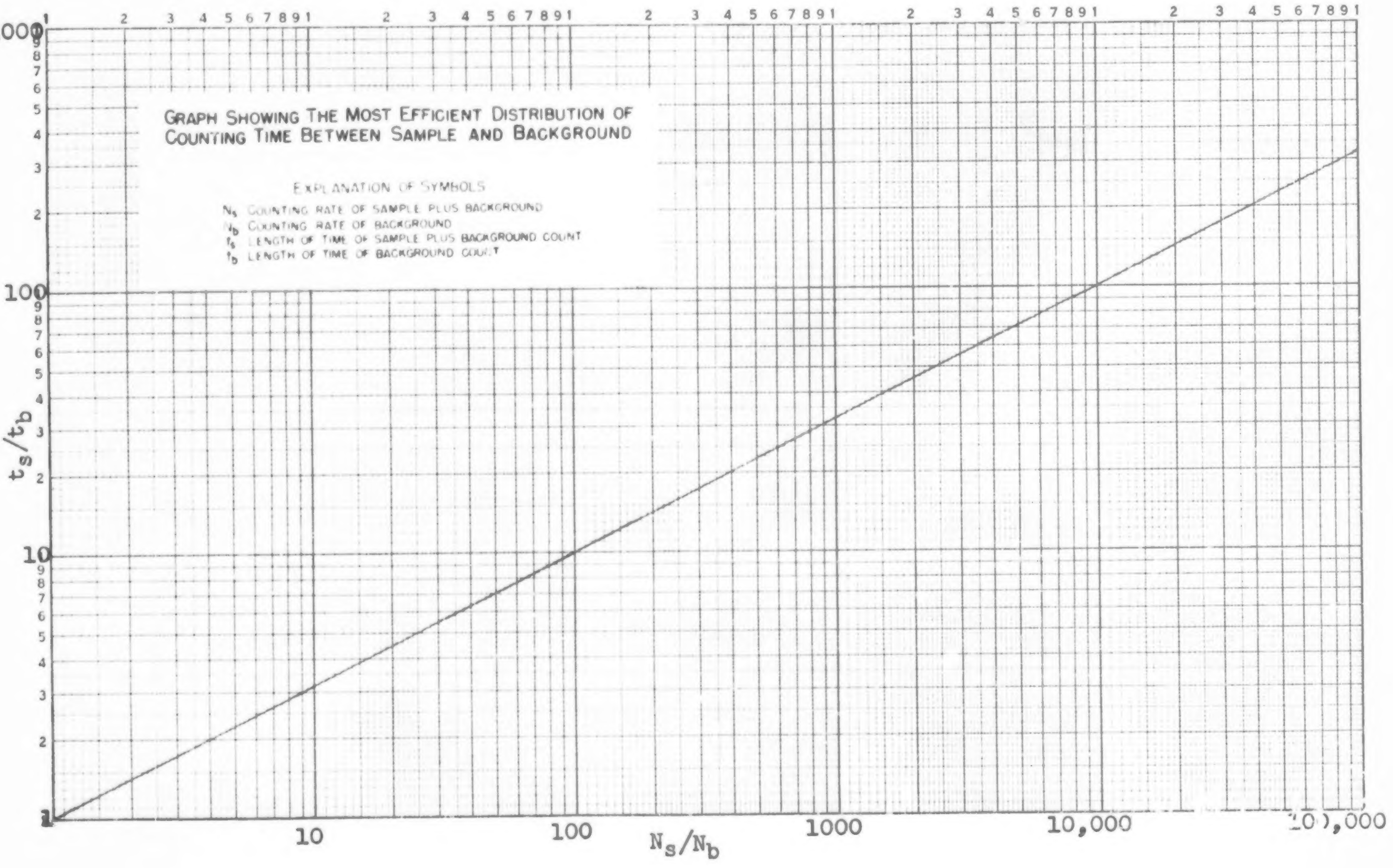


STATISTICAL LIMITS OF COUNTER RELIABILITY

P represents the probability that the observations show a greater deviation from the Poisson distribution than would be expected from chance alone.

USE

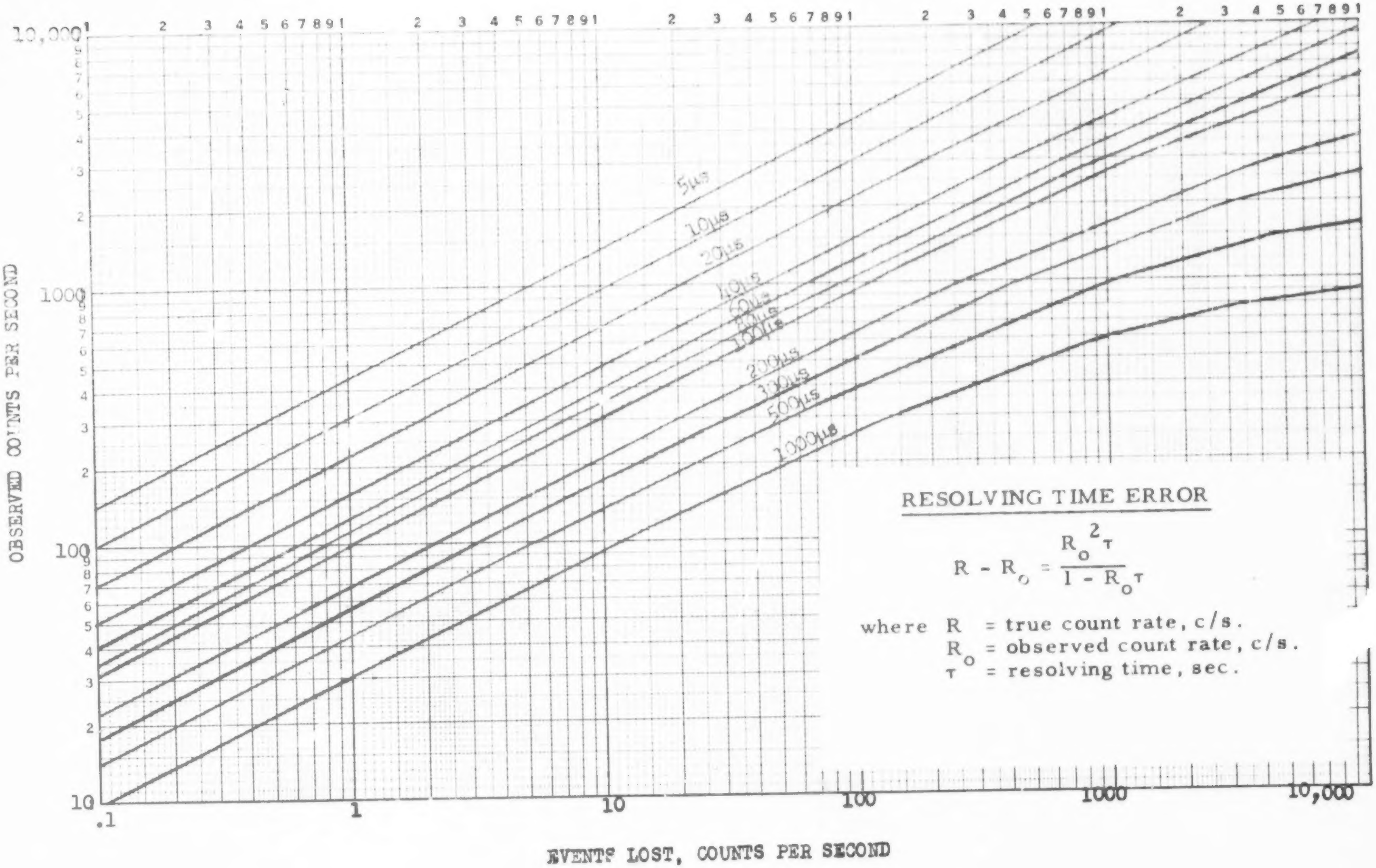
From a series of replicate counting measurements compute S_n, σ_n and R.F. (see p. 48). Enter graph with number of observations and R.F. Corresponding point represents value of P. If P lies between 0.10 and 0.90, instrument operation is probably satisfactory. If P is less than 0.02 or greater than 0.98, instrument is not operating satisfactorily



GRAPH SHOWING THE MOST EFFICIENT DISTRIBUTION OF COUNTING TIME BETWEEN SAMPLE AND BACKGROUND

EXPLANATION OF SYMBOLS

N_s COUNTING RATE OF SAMPLE PLUS BACKGROUND
N_b COUNTING RATE OF BACKGROUND
t_s LENGTH OF TIME OF SAMPLE PLUS BACKGROUND COUNT
t_b LENGTH OF TIME OF BACKGROUND COUNT



RESOLVING TIME ERROR

$$R - R_o = \frac{R_o^2 \tau}{1 - R_o \tau}$$

where R = true count rate, c/s.
R_o = observed count rate, c/s.
τ = resolving time, sec.

TABLE OF SATURATION THICKNESS BACKSCATTER CORRECTIONS FOR BETA EMITTERS

MATERIAL	Aluminum	Glass	Copper	Silver	Platinum
End Window GM Counter 23% Geometry - 3 mg/cm^2 window*	1.28	1.22	1.46	1.60	1.70

* For beta emitters of greater than 0.6 Mev energy (U.S. Bureau of Standards Handbook 51).

Sample Calculation

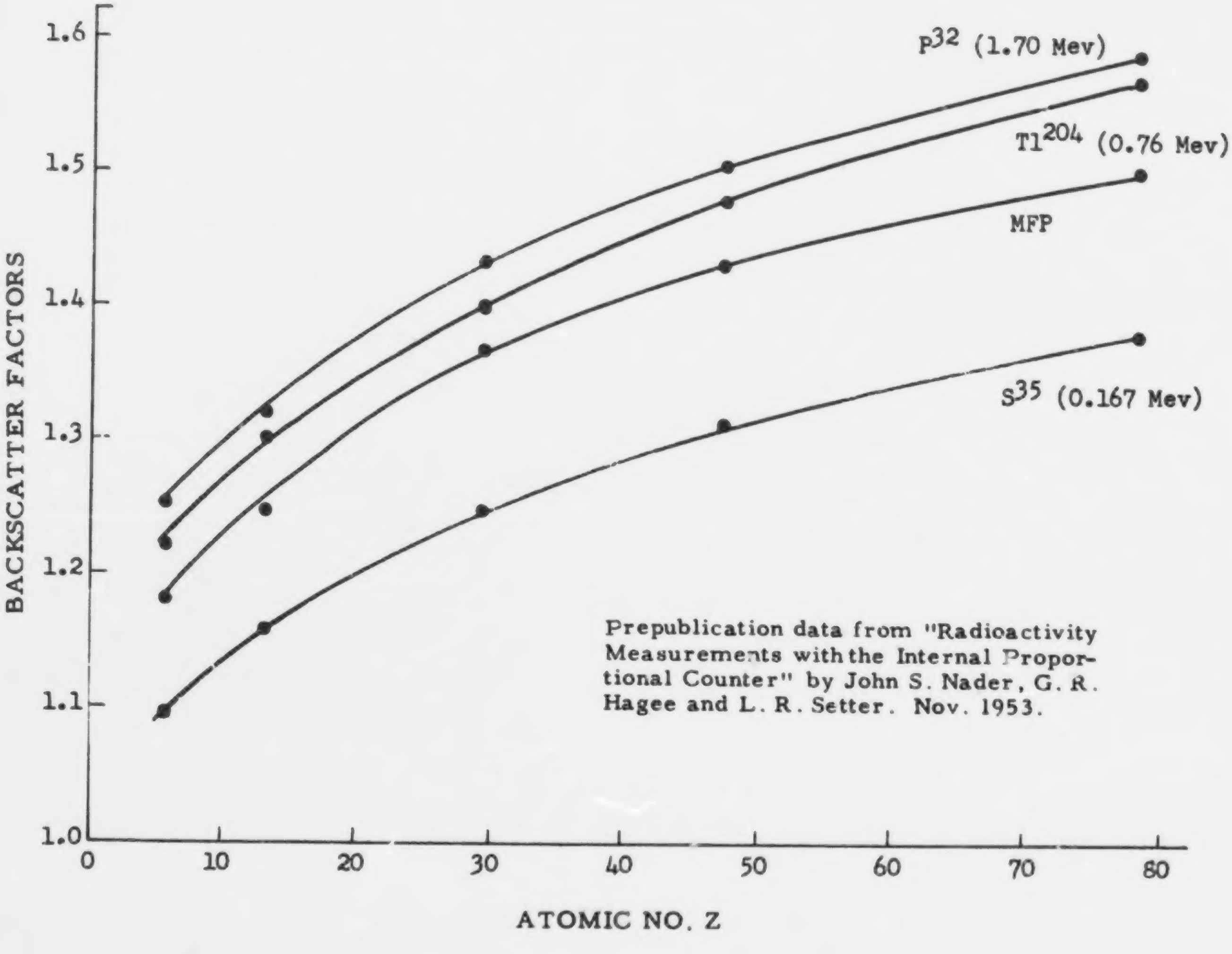
A count rate of 55 counts/minute observed on a 3 mg/cm^2 end-window GM scaler unit when a Phosphorus-32 sample on a platinum disk (1 mm thickness) is mounted in the scaling unit with a 23% geometry. Determine the approximate beta emission rate.

Approximate Emission Rate (beta particles/minute) =

$$\frac{\text{Observed Counting Rate (counts/minute)}}{\text{Counter efficiency (no backing) x Backscatter Correction}}$$

$$\text{Beta particles per minute} = \frac{55}{(0.23)(1.70)} = 145.8$$

BACKSCATTER FACTORS FOR INTERNAL PROPORTIONAL COUNTERS



Prepublication data from "Radioactivity Measurements with the Internal Proportional Counter" by John S. Nader, G. R. Hagee and L. R. Setter. Nov. 1953.

DECAY CORRECTIONS, GRAPHS, AND NOMOGRAPHS

The exponential form of the equation which describes the rate of physical decay of radionuclides is $A = A_o e^{-\lambda t}$; where A is the radioactivity at any time t, A_o the original activity at zero time and e the base of natural logarithms. The following decay tables, semi-log plot, and nomographs each provide a means of solving the exponential equation for A/A_o, the fraction of radioactivity remaining at any time.

The decay table lists the value for $e^{-\lambda t}$ for the larger time intervals (t) shown in the left-hand margin and for smaller time intervals (t) on the column headings across the top of the table. The table for a particular nuclide or isotope can be used conveniently for the recorded time unit and interpolations can be made with fair accuracy for times which fall between those listed in the table. The values for A/A_o (or its equal $e^{-\lambda t}$) have been rounded off to four places to facilitate such interpolations.

The numerical value of the λ factor, which appears on the left side of the heading of each table, was calculated from $\lambda t = (.69315/T\frac{1}{2})t$ for the time interval used in the tables. The half-life ($T\frac{1}{2}$) value used to make this calculation for each nuclide is the first entry in the list of half-lives as published in the 1952 revision of the Table of Isotopes, which is reproduced as an Appendix to this Handbook.

The calculated tables may be used directly for time intervals up to approximately three half-lives in most cases. The semi-log plot is less accurate than the tables, however, it is extended to seven half-lives. If it is desirable to use the tables for times beyond those for direct entries the value of $e^{-\lambda t}$ may be obtained by a multiplication of two or more correction factors which are shown in the tables as follows: If $t = t_1 + t_2 + t_3$, where t_1, t_2, and t_3 are time intervals shown in the table, the equation $A/A_o = e^{-\lambda t}$ becomes $A/A_o = e^{-\lambda(t_1 + t_2 + t_3)} = e^{-(\lambda t_1 + \lambda t_2 + \lambda t_3)} = e^{-\lambda t_1} \times e^{-\lambda t_2} \times e^{-\lambda t_3}$. The values for $e^{-\lambda t_1}$, $e^{-\lambda t_2}$, and $e^{-\lambda t_3}$, may be read directly from the table. A specific example of this usage is to find the fraction of original activity of P^{32} remaining after 60 days and 9 hours. Since the tables do not go beyond 47.5 days, two or three time intervals whose sum will be 60 days and 9 hours can be used. Choose two such time intervals wherever possible and in this case take t_1 = 47 days and t_2 = 13 days and 9 hours, and obtain the corresponding decay correction factor for these time intervals from the table in the usual manner:

$$e^{-\lambda t_1} \text{ for 47 d} = .1024 \text{ and } e^{-\lambda t_2} \text{ for 13 days 9 hours} = .5229$$

$$e^{-\lambda t_1} \times e^{\lambda t_2} = .1024 \times .5229 = .0535 = A/A_o$$

Compare this with the example cited on the semi-log plot which follows the decay tables. Here the value of .0535 can be read directly.

A description of the use of the nomograph precedes the nomograph. It should be remembered, however, that this nomograph gives A_o/A which is the reciprocal of the fraction of activity left (A/A_o) after any time interval.

CALCIUM - 45

λ factor (1 day) = 0.00456

$T_{\frac{1}{2}}$ = 152 days

Days	0	1	2	3	4	5	6	7	8	9
0	-----	.9955	.9909	.9864	.9819	.9775	.9730	.9686	.9642	.9598
10	.9554	.9511	.9467	.9424	.9382	.9339	.9296	.9254	.9212	.9170
20	.9128	.9087	.9045	.9004	.8963	.8923	.8882	.8842	.8801	.8761
30	.8721	.8682	.8642	.8603	.8564	.8525	.8486	.8447	.8409	.8371
40	.8333	.8295	.8257	.8219	.8182	.8145	.8108	.8071	.8034	.7998
50	.7961	.7925	.7889	.7853	.7817	.7782	.7746	.7711	.7676	.7641
60	.7606	.7572	.7537	.7503	.7469	.7435	.7401	.7367	.7334	.7300
70	.7267	.7234	.7201	.7169	.7136	.7103	.7071	.7039	.7007	.6975
80	.6943	.6912	.6880	.6849	.6818	.6787	.6756	.6725	.6695	.6664
90	.6634	.6604	.6574	.6544	.6514	.6484	.6455	.6425	.6396	.6367
100	.6338	.6309	.6281	.6252	.6224	.6195	.6167	.6139	.6111	.6083
110	.6056	.6028	.6001	.5973	.5946	.5919	.5892	.5865	.5839	.5812
120	.5786	.5759	.5733	.5707	.5681	.5655	.5629	.5604	.5578	.5553
130	.5528	.5503	.5478	.5453	.5428	.5403	.5379	.5354	.5330	.5305
140	.5281	.5257	.5233	.5210	.5186	.5162	.5139	.5115	.5092	.5069
150	.5046	.5023	.5000	.4977	.4955	.4932	.4910	.4887	.4865	.4843
160	.4821	.4799	.4777	.4755	.4734	.4712	.4691	.4670	.4648	.4627
170	.4606	.4585	.4564	.4543	.4523	.4502	.4482	.4461	.4441	.4421
180	.4401	.4381	.4361	.4341	.4321	.4302	.4282	.4263	.4243	.4224
190	.4205	.4185	.4166	.4147	.4129	.4110	.4091	.4073	.4054	.4036
200	.4017	.3999	.3981	.3963	.3945	.3927	.3909	.3891	.3873	.3856
210	.3838	.3821	.3803	.3786	.3769	.3752	.3735	.3718	.3701	.3684
220	.3667	.3650	.3634	.3617	.3601	.3584	.3568	.3552	.3536	.3520
230	.3504	.3488	.3472	.3456	.3440	.3425	.3409	.3393	.3378	.3363
240	.3347	.3332	.3317	.3302	.3287	.3272	.3257	.3242	.3227	.3213
250	.3198	.3184	.3169	.3155	.3140	.3126	.3112	.3098	.3084	.3070
260	.3056	.3042	.3028	.3014	.3000	.2987	.2973	.2960	.2946	.2933
270	.2919	.2906	.2893	.2880	.2867	.2854	.2841	.2828	.2815	.2802
280	.2789	.2777	.2764	.2751	.2739	.2726	.2714	.2702	.2689	.2677
290	.2665	.2653	.2641	.2629	.2617	.2605	.2593	.2581	.2569	.2558
300	.2546	.2534	.2523	.2512	.2500	.2489	.2477	.2466	.2455	.2444
310	.2433		.2411		.2389		.2367		.2346	
320	.2324		.2303		.2282		.2261		.2241	
330	.2221		.2200		.2180		.2161		.2141	
340	.2122		.2102		.2083		.2064		.2046	
350	.2027		.2009		.1990		.1972		.1954	
360	.1937		.1919		.1902		.1884		.1867	
370	.1850		.1834		.1817		.1800		.1784	
380	.1768		.1752		.1736		.1720		.1705	
390	.1689		.1674		.1659		.1644		.1629	

CALCIUM - 45

Days	0	2	4	6	8
400	.1614	.1599	.1585	.1570	.1556
410	.1542	.1528	.1514	.1500	.1487
420	.1473	.1460	.1446	.1433	.1420
430	.1407	.1395	.1382	.1369	.1357
440	.1345	.1332	.1320	.1308	.1297
450	.1285	.1273	.1262	.1250	.1239
460	.1228	.1216	.1205	.1194	.1184
470	.1173	.1162	.1152	.1141	.1131
480	.1121	.1110	.1100	.1090	.1080
490	.1071	.1061	.1051	.1042	.1032
500	.1023	.1013	.1004		

COBALT - 60

λ factor (1 month) = 0.01096

$T_{\frac{1}{2}}$ = 5.27 years

Months	0	1	2	3	4	5	6	7	8	9
0	-----	.9891	.9783	.9676	.9571	.9467	.9363	.9262	.9160	.9061
10	.8962	.8864	.8768	.8673	.8578	.8484	.8391	.8300	.8209	.8120
20	.8032	.7944	.7858	.7772	.7687	.7603	.7520	.7439	.7357	.7277
30	.7198	.7120	.7042	.6965	.6889	.6814	.6739	.6666	.6594	.6521
40	.6451	.6380	.6311	.6242	.6174	.6107	.6040	.5974	.5909	.5844
50	.5781	.5718	.5655	.5594	.5533	.5473	.5413	.5354	.5296	.5238
60	.5181	.5124	.5068	.5013	.4958	.4905	.4851	.4798	.4746	.4694
70	.4643	.4592	.4540	.4493	.4444	.4396	.4347	.4300	.4253	.4207
80	.4161	.4116	.4071	.4026	.3982	.3939	.3896	.3854	.3812	.3770
90	.3729	.3688	.3648	.3608	.3569	.3530	.3492	.3453	.3416	.3379
100	.3342	.3305	.3269	.3234	.3199	.3164	.3129	.3095	.3061	.3028
110	.2995	.2962	.2930	.2898	.2866	.2835	.2804	.2774	.2743	.2714
120	.2684	.2655	.2626	.2597	.2569	.2541	.2513	.2486	.2459	.2432
130	.2405	.2379	.2353	.2327	.2302	.2277	.2252	.2228	.2203	.2179
140	.2156	.2132	.2109	.2086	.2063					

COPPER - 64

λ factor (7.5 minutes) = 0.00677 $T_{\frac{1}{2}}$ = 12.8 hours

Minutes Hours	0	7.5	15.0	22.5	30.0	37.5	45.0	52.5
0	-----	.9934	.9866	.9799	.9733	.9667	.9602	.9537
1	.9473	.9409	.9345	.9282	.9220	.9158	.9096	.9034
2	.8973	.8913	.8853	.8793	.8734	.8675	.8616	.8558
3	.8500	.8443	.8386	.8329	.8273	.8217	.8162	.8107
4	.8052	.7998	.7944	.7890	.7837	.7784	.7732	.7680
5	.7628	.7576	.7525	.7474	.7424	.7374	.7324	.7275
6	.7226	.7177	.7128	.7080	.7033	.6985	.6938	.6891
7	.6845	.6798	.6753	.6707	.6662	.6617	.6572	.6528
8	.6484	.6440	.6396	.6353	.6311	.6268	.6226	.6184
9	.6142	.6101	.6059	.6018	.5978	.5937	.5897	.5858
10	.5818	.5779	.5740	.5701	.5663	.5625	.5587	.5549
11	.5511	.5474	.5437	.5401	.5364	.5328	.5292	.5256
12	.5221	.5186	.5151	.5116	.5081	.5047	.5013	.4979
13	.4946	.4912	.4879	.4846	.4813	.4781	.4749	.4717
14	.4685	.4653	.4622	.4591	.4560	.4529	.4498	.4468
15	.4438	.4408	.4378	.4349	.4319	.4290	.4261	.4233
16	.4204	.4176	.4147	.4119	.4092	.4064	.4037	.4009
17	.3982	.3955	.3929	.3902	.3876	.3850	.3824	.3798
18	.3772	.3747	.3722	.3697	.3672	.3647	.3622	.3598
19	.3573	.3549	.3525	.3501	.3478	.3455	.3431	.3408
20	.3385	.3362	.3340	.3317	.3295	.3272	.3250	.3228
21	.3207	.3185	.3164	.3142	.3121	.3100	.3079	.3058
22	.3038	.3017	.2997	.2976	.2956	.2936	.2917	.2897
23	.2877	.2858	.2839	.2820	.2801	.2782	.2763	.2744
24	.2726	.2707	.2689	.2671	.2653	.2635	.2617	.2600
25	.2582	.2565	.2547	.2530	.2513	.2496	.2479	.2463
26	.2446		.2413		.2381		.2349	
27	.2317		.2286		.2255		.2225	
28	.2195		.2165		.2136		.2107	
29	.2079		.2051		.2024		.1996	
30	.1970		.1943		.1917		.1891	
31	.1866		.1841		.1816		.1791	
32	.1767		.1744		.1720		.1697	
33	.1674		.1652		.1629		.1607	
34	.1586		.1565		.1544		.1523	
35	.1502		.1482		.1462		.1442	
36	.1423		.1404		.1385		.1366	
37	.1348		.1330		.1312		.1294	
38	.1277		.1260		.1243		.1226	
39	.1210		.1193		.1177		.1162	

GOLD - 199

λ factor (1 hour) = 0.009168

$T_{\frac{1}{2}}$ = 3.15 days

Hours	0	1	2	3	4	5	6	7	8	9
0	-----	.9908	.9819	.9729	.9640	.9552	.9465	.9378	.9293	.9208
10	.9124	.9040	.8958	.8876	.8795	.8715	.8636	.8556	.8479	.8401
20	.8324	.8249	.8173	.8099	.8025	.7952	.7879	.7807	.7736	.7665
30	.7595	.7526	.7457	.7389	.7322	.7255	.7189	.7123	.7058	.6994
40	.6930	.6867	.6804	.6742	.6680	.6619	.6559	.6499	.6440	.6381
50	.6323	.6265	.6208	.6151	.6095	.6039	.5985	.5930	.5875	.5822
60	.5769	.5716	.5664	.5612	.5561	.5510	.5460	.5410	.5361	.5312
70	.5263	.5215	.5168	.5121	.5074	.5028	.4982	.4936	.4891	.4847
80	.4802	.4758	.4715	.4672	.4629	.4587	.4545	.4504	.4463	.4422
90	.4381	.4342	.4302	.4263	.4224	.4185	.4147	.4109	.4072	.4035
100	.3998	.3961	.3925	.3889	.3854	.3819	.3784	.3749	.3715	.3681
110	.3647	.3614	.3581	.3548	.3516	.3484	.3452	.3421	.3390	.3358
120	.3328	.3298	.3267	.3238	.3208	.3179	.3150	.3121	.3093	.3064
130	.3036	.3009	.2981	.2954	.2927	.2900	.2874	.2848	.2822	.2796
140	.2770	.2745	.2720	.2695	.2671	.2646	.2622	.2598	.2574	.2551
150	.2528	.2504	.2482	.2459	.2437	.2414	.2392	.2370	.2349	.2327
160	.2306	.2285	.2264	.2244	.2223	.2203	.2183	.2163	.2143	
170	.2104		.2066		.2028		.1991		.1955	
180	.1920		.1885		.1851		.1817		.1784	
190	.1752		.1720		.1689		.1658		.1628	
200	.1598		.1569		.1541		.1513		.1485	
210	.1458		.1432		.1406		.1380		.1355	
220	.1330		.1306		.1282		.1259		.1236	
230	.1214		.1192		.1170		.1149		.1128	
240	.1107		.1087		.1068		.1048		.1029	
250	.1010		.0992		.0974		.0956		.0939	

GOLD - 198

λ factor (30 minutes) = 0.00537

$T_{\frac{1}{2}}$ = 2.69 days
64.6 hours

Hours	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-----	.9946	.9893	.9840	.9787	.9735	.9683	.9631	.9579	.9528
5	.9477	.9427	.9376	.9326	.9276	.9226	.9177	.9128	.9079	.9030
10	.8982	.8934	.8886	.8838	.8791	.8744	.8697	.8650	.8604	.8558
15	.8512	.8466	.8421	.8376	.8331	.8287	.8242	.8198	.8154	.8110
20	.8067	.8024	.7981	.7938	.7896	.7853	.7811	.7769	.7728	.7686
25	.7645	.7604	.7564	.7523	.7483	.7443	.7403	.7363	.7324	.7285
30	.7246	.7207	.7168	.7130	.7092	.7054	.7016	.6978	.6941	.6904
35	.6867	.6830	.6793	.6757	.6721	.6685	.6649	.6613	.6578	.6543
40	.6508	.6473	.6438	.6404	.6369	.6335	.6301	.6268	.6234	.6201
45	.6167	.6134	.6102	.6069	.6036	.6004	.5972	.5940	.5908	.5876
50	.5845	.5814	.5783	.5752	.5721	.5690	.5660	.5629	.5599	.5569
55	.5539	.5510	.5480	.5451	.5422	.5393	.5364	.5335	.5306	.5278
60	.5250	.5222	.5194	.5166	.5138	.5111	.5083	.5056	.5029	.5002
65	.4975	.4949	.4922	.4896	.4870	.4844	.4818	.4792	.4766	.4741
70	.4715	.4690	.4665	.4640	.4615	.4590	.4566	.4541	.4517	.4493
75	.4469	.4445	.4421	.4397	.4374	.4350	.4327	.4304	.4281	.4258
80	.4235	.4212	.4190	.4167	.4145	.4123	.4101	.4079	.4057	.4035
85	.4014	.3992	.3971	.3949	.3928	.3907	.3886	.3866	.3845	.3824
90	.3804	.3783	.3763	.3743	.3723	.3703	.3683	.3663	.3644	.3624
95	.3605	.3586	.3566	.3547	.3528	.3509	.3491	.3472	.3453	.3435
100	.3416	.3398	.3380	.3362	.3344	.3326	.3308	.3290	.3273	.3255
105	.3238	.3220	.3203	.3186	.3169	.3152	.3135	.3118	.3102	.3085
110	.3068	.3052	.3036	.3019	.3003	.2987	.2971	.2955	.2939	.2924
115	.2908	.2892	.2877	.2862	.2846	.2831	.2816	.2801	.2786	.2771
120	.2756	.2741	.2727	.2712	.2697	.2683	.2669	.2654	.2640	.2626
125	.2612	.2598	.2584	.2570	.2556	.2543	.2529	.2516	.2502	.2489
130	.2475		.2449		.2423		.2397		.2371	
135	.2346		.2321		.2296		.2272		.2247	
140	.2223		.2200		.2176		.2153		.2130	
145	.2107		.2085		.2062		.2040		.2018	
150	.1997		.1976		.1955		.1934		.1913	
155	.1892		.1872		.1852		.1832		.1813	
160	.1794		.1774		.1755		.1737		.1718	
165	.1700		.1682		.1664		.1646		.1628	
170	.1611		.1594		.1577		.1560		.1543	
175	.1527		.1510		.1494		.1478		.1462	
180	.1447		.1431		.1416		.1401		.1386	
185	.1371		.1357		.1342		.1328		.1314	
190	.1300		.1286		.1272		.1258		.1245	
195	.1232		.1218		.1205		.1193		.1180	
200	.1167		.1155		.1142		.1130		.1118	
205	.1106		.1094		.1083		.1071		.1060	

IODINE - 131

λ factor (2 hours) = 0.007096

$T_{\frac{1}{2}}$ = 8.14 days

Hours Days	0	2	4	6	8	10	12	14	16	18	20	22
0	-----	.9929	.9859	.9789	.9720	.9651	.9583	.9515	.9448	.9381	.9315	.9249
1	.9183	.9119	.9055	.8991	.8927	.8864	.8801	.8739	.8677	.8616	.8555	.8494
2	.8434	.8374	.8315	.8256	.8198	.8140	.8082	.8025	.7968	.7912	.7856	.7800
3	.7745	.7690	.7636	.7583	.7529	.7476	.7423	.7370	.7318	.7267	.7215	.7164
4	.7113	.7063	.7013	.6964	.6914	.6865	.6817	.6769	.6721	.6673	.6626	.6579
5	.6532	.6486	.6440	.6395	.6350	.6305	.6261	.6216	.6172	.6129	.6085	.6042
6	.6000	.5957	.5915	.5873	.5832	.5790	.5749	.5709	.5668	.5628	.5588	.5549
7	.5510	.5471	.5432	.5393	.5355	.5317	.5280	.5243	.5206	.5169	.5132	.5096
8	.5060	.5024	.4989	.4953	.4918	.4884	.4849	.4815	.4781	.4747	.4713	.4680
9	.4647	.4614	.4581	.4549	.4517	.4485	.4453	.4422	.4390	.4360	.4329	.4298
10	.4268	.4238	.4208	.4178	.4148	.4119	.4090	.4061	.4032	.4004	.3975	.3947
11	.3919	.3891	.3864	.3837	.3810	.3782	.3756	.3729	.3703	.3677	.3651	.3625
12	.3599	.3574	.3549	.3524	.3499	.3474	.3449	.3425	.3401	.3377	.3353	.3329
13	.3305	.3282	.3259	.3236	.3213	.3190	.3168	.3145	.3123	.3101	.3079	.3057
14	.3036	.3014	.2993	.2972	.2951	.2930	.2909	.2889	.2868	.2848	.2828	.2808
15	.2788	.2768	.2749	.2729	.2710	.2691	.2672	.2653	.2634	.2615	.2597	.2578
16	.2560	.2542	.2524	.2506	.2489	.2471	.2454	.2436	.2419	.2402	.2385	.2368
17	.2351			.2302			.2253			.2206		
18	.2159			.2114			.2069			.2026		
19	.1983			.1941			.1900			.1860		
20	.1821			.1783			.1745			.1709		
21	.1673			.1637			.1603			.1569		
22	.1536			.1504			.1472			.1441		
23	.1411			.1381			.1352			.1323		
24	.1295			.1268			.1241			.1215		
25	.1190			.1165			.1140			.1116		
26	.1093			.1070			.1047			.1025		
27	.1003			.0982			.0962			.0941		
28	.0922											

IRON - 55

λ factor (20 days) = 0.0129

$T_{\frac{1}{2}}$ = 2.94 years

Days	0	20	40	60	80
0	-----	.9872	.9745	.9619	.9496
100	.9374	.9254	.9136	.9019	.8902
200	.8788	.8675	.8564	.8454	.8345
300	.8238	.8133	.8028	.7925	.7823
400	.7723	.7624	.7526	.7430	.7334
500	.7240	.7147	.7055	.6965	.6876
600	.6787	.6700	.6614	.6529	.6446
700	.6362	.6281	.6200	.6121	.6042
800	.5965	.5888	.5812	.5738	.5664
900	.5592	.5519	.5449	.5379	.5310
1000	.5242	.5174	.5108	.5042	.4978
1100	.4914	.4851	.4788	.4727	.4666
1200	.4607	.4548	.4489	.4431	.4374
1300	.4318	.4263	.4208	.4154	.4101
1400	.4048	.3996	.3945	.3894	.3844
1500	.3795	.3746	.3698	.3651	.3604
1600	.3558	.3512	.3467	.3423	.3378
1700	.3335	.3292	.3250	.3208	.3167
1800	.3126	.3086	.3047	.3008	.2969
1900	.2931	.2893	.2856	.2820	.2783
2000	.2747	.2712	.2678	.2643	.2609
2100	.2576	.2543	.2510	.2478	.2446
2200	.2414	.2384	.2353	.2323	.2293
2300	.2264	.2234	.2206	.2178	.2150
2400	.2122	.2095	.2068	.2041	.2015
2500	.1989		.1938		.1889
2600	.1865		.1817		.1771
2700	.1748		.1704		.1660
2800	.1639		.1597		.1556
2900	.1536		.1497		.1459
3000	.1440		.1404		.1368
3100	.1350		.1316		.1282
3200	.1266		.1233		.1202
3300	.1186		.1156		.1127

IRON - 59

λ factor (8 hours) = 0.00512 $T_{\frac{1}{2}}$ = 45.1 days

Hours Days	0	8	16	24	32	40	48	56	64
0	-----	.9949	.9899	.9847	.9797	.9747	.9698	.9647	.9598
3	.9549	.9501	.9452	.9404	.9356	.9308	.9261	.9213	.9166
6	.9119	.9073	.9026	.8980	.8934	.8889	.8843	.8798	.8753
9	.8708	.8664	.8619	.8575	.8532	.8488	.8444	.8401	.8359
12	.8316	.8273	.8231	.8189	.8147	.8106	.8064	.8023	.7982
15	.7941	.7900	.7860	.7820	.7780	.7740	.7700	.7661	.7622
18	.7584	.7544	.7506	.7468	.7430	.7391	.7354	.7316	.7279
21	.7241	.7204	.7168	.7131	.7095	.7058	.7022	.6987	.6951
24	.6915	.6880	.6845	.6810	.6775	.6740	.6706	.6672	.6638
27	.6603	.6570	.6536	.6503	.6469	.6437	.6404	.6371	.6338
30	.6306	.6274	.6242	.6210	.6178	.6147	.6115	.6084	.6053
33	.6022	.5991	.5961	.5930	.5900	.5870	.5840	.5810	.5780
36	.5750	.5721	.5692	.5663	.5634	.5605	.5577	.5548	.5519
39	.5491	.5463	.5436	.5407	.5380	.5353	.5325	.5298	.5271
42	.5244	.5217	.5190	.5164	.5138	.5111	.5085	.5059	.5033
45	.5008	.4982	.4956	.4931	.4906	.4881	.4856	.4831	.4807
48	.4782		.4733		.4685		.4637		.4590
51	.4567		.4520		.4474		.4428		.4383
54	.4361		.4316		.4272		.4229		.4186
57	.4164		.4122		.4080		.4038		.3997
60	.3976		.3936		.3896		.3856		.3817
63	.3797		.3759		.3720		.3682		.3645
66	.3626		.3589		.3553		.3517		.3481
69	.3463		.3428		.3393		.3358		.3324
72	.3307		.3273		.3240		.3207		.3174
75	.3158		.3126		.3094		.3062		.3031
78	.3016		.2985		.2954		.2924		.2894
81	.2880		.2850		.2821		.2793		.2764
84	.2750		.2722		.2694		.2667		.2639
87	.2626		.2599		.2573		.2546		.2521
90	.2508			.2469			.2432		
93	.2395			.2358			.2322		
96	.2287			.2252			.2218		
99	.2184			.2150			.2118		
102	.2085			.2054			.2022		
105	.1991			.1961			.1931		
108	.1902			.1873			.1844		
111	.1816			.1788			.1761		
114	.1734			.1708			.1682		
117	.1656			.1631			.1606		

LEAD - 210 (RaD)

λ factor (100 days) = 0.00863

$T_{\frac{1}{2}}$ - 22 years

Days	0	100	200	300	400	500	600	700	800	900
0	-----	.9914	.9828	.9744	.9661	.9577	.9495	.9414	.9332	.9252
1000	.9173	.9094	.9016	.8939	.8862	.8785	.8710	.8636	.8561	.8487
2000	.8415	.8342	.8270	.8200	.8129	.8059	.7990	.7921	.7853	.7786
3000	.7718	.7652	.7587	.7521	.7456	.7393	.7329	.7266	.7204	.7142
4000	.7080	.7019	.6959	.6899	.6840	.6781	.6723	.6665	.6608	.6551
5000	.6495	.6439	.6383	.6329	.6274	.6220	.6167	.6114	.6061	.6009
6000	.5958	.5906	.5856	.5805	.5756	.5706	.5657	.5609	.5560	.5512
7000	.5465	.5418	.5371	.5325	.5279	.5234	.5189	.5144	.5100	.5057
8000	.5013	.4970	.4927	.4885	.4843	.4801	.4760	.4719	.4679	.4638
9000	.4598		.4520		.4442		.4366		.4292	
10000	.4218		.4146		.4075		.4005		.3936	
11000	.3869		.3803		.3738		.3674		.3611	
12000	.3549		.3489		.3429		.3370		.3312	
13000	.3256									

PHOSPHORUS - 32

λ factor (3 hours) = 0.00606 $T_{\frac{1}{2}}$ - 14.3 days

Hours Days	0	3	6	9	12	15	18	21
0	-----	.9940	.9880	.9820	.9761	.9702	.9643	.9585
1	.9527	.9469	.9412	.9355	.9299	.9243	.9187	.9131
2	.9076	.9021	.8967	.8913	.8859	.8805	.8752	.8699
3	.8646	.8594	.8542	.8491	.8439	.8388	.8338	.8287
4	.8237	.8187	.8138	.8089	.8040	.7991	.7943	.7895
5	.7847	.7800	.7753	.7706	.7659	.7613	.7567	.7521
6	.7476	.7431	.7386	.7341	.7297	.7253	.7209	.7166
7	.7122	.7079	.7036	.6994	.6952	.6910	.6868	.6826
8	.6785	.6744	.6703	.6663	.6623	.6583	.6543	.6503
9	.6464	.6425	.6386	.6348	.6309	.6271	.6233	.6196
10	.6158	.6121	.6084	.6047	.6011	.5974	.5938	.5902
11	.5867	.5831	.5796	.5761	.5726	.5692	.5657	.5623
12	.5589	.5555	.5522	.5488	.5455	.5422	.5390	.5357
13	.5325	.5292	.5260	.5229	.5197	.5166	.5135	.5104
14	.5073	.5042	.5012	.4981	.4951	.4921	.4892	.4862
15	.4833		.4774		.4717		.4660	
16	.4604		.4549		.4494		.4440	
17	.4386		.4333		.4281		.4230	
18	.4179		.4128		.4078		.4029	
19	.3981		.3933		.3885		.3838	
20	.3792		.3747		.3702		.3657	
21	.3613		.3569		.3526		.3484	
22	.3442		.3400		.3359		.3319	
23	.3279		.3239		.3200		.3162	
24	.3124		.3086		.3049		.3012	
25	.2976		.2940		.2905		.2870	
26	.2835		.2801		.2767		.2734	
27	.2701		.2668		.2636		.2604	
28	.2573		.2542		.2512		.2481	
29	.2451		.2422		.2393		.2364	
30	.2335				.2279			
31	.2225				.2172			
32	.2120				.2069			
33	.2019				.1971			
34	.1924				.1878			
35	.1833				.1789			
36	.1746				.1704			
37	.1663				.1624			
38	.1585				.1547			
39	.1510				.1473			

POTASSIUM - 42

λ factor (10 minutes) = 0.00932

$T_{\frac{1}{2}}$ = 12.4 hours

Minutes Hours	0	10	20	30	40	50	60	70	80	90	100	110
0	-----	.9907	.9815	.9724	.9634	.9545	.9456	.9368	.9281	.9195	.9110	.9026
2	.8942	.8859	.8777	.8695	.8615	.8535	.8456	.8377	.8299	.8222	.8146	.8071
4	.7996	.7922	.7848	.7775	.7703	.7632	.7561	.7491	.7421	.7352	.7284	.7217
6	.7150	.7083	.7018	.6953	.6888	.6824	.6761	.6698	.6636	.6574	.6513	.6453
8	.6393	.6334	.6275	.6217	.6159	.6102	.6045	.5989	.5934	.5879	.5824	.5770
10	.5717	.5664	.5611	.5559	.5507	.5456	.5406	.5356	.5306	.5257	.5208	.5160
12	.5112	.5064	.5017	.4971	.4925	.4879	.4834	.4789	.4744	.4700	.4657	.4614
14	.4571	.4528	.4486	.4445	.4404	.4363	.4322	.4282	.4242	.4203	.4164	.4125
16	.4087	.4049	.4012	.3975	.3938	.3901	.3865	.3829	.3794	.3758	.3723	.3689
18	.3655	.3621	.3587	.3554	.3521	.3488	.3456	.3424	.3392	.3361	.3330	.3299
20	.3268	.3238	.3208	.3178	.3148	.3119	.3090	.3062	.3033	.3005	.2977	.2950
22	.2922	.2895	.2868	.2842	.2815	.2789	.2763	.2738	.2712	.2687	.2662	.2637
24	.2613	.2589	.2565	.2541	.2517	.2494	.2471	.2448	.2425	.2403	.2380	.2358
26	.2336	.2315	.2293	.2272	.2251	.2230	.2209	.2189	.2169	.2149	.2129	.2109
28	.2089	.2070	.2051	.2032	.2013	.1994	.1976	.1957	.1939	.1921	.1903	.1886
30	.1868	.1851	.1834	.1817	.1800	.1783	.1767	.1750	.1734	.1718	.1702	.1686
32	.1671	.1655	.1640	.1624	.1609	.1594	.1580	.1565	.1551	.1536	.1522	.1508
34	.1494	.1480	.1466	.1453	.1439	.1426	.1413	.1399	.1386	.1374	.1361	.1348
36	.1336	.1323	.1311	.1299	.1287	.1275	.1263	.1251	.1240	.1228	.1217	.1206
38	.1194	.1183	.1172	.1161	.1151	.1140	.1129	.1119	.1109	.1098	.1088	.1078
40	.1068	.1058	.1048	.1039	.1029	.1019	.1010	.1001	.0991			

SODIUM - 24

λ factor (10 minutes) = 0.00767

$T_{\frac{1}{2}}$ = 15.06 hours

Minutes Hours	0	10	20	30	40	50
0	-----	.9923	.9848	.9773	.9698	.9624
1	.9550	.9477	.9405	.9333	.9262	.9191
2	.9121	.9051	.8982	.8913	.8845	.8777
3	.8710	.8644	.8578	.8512	.8447	.8383
4	.8319	.8255	.8192	.8129	.8067	.8005
5	.7944	.7884	.7823	.7764	.7704	.7645
6	.7587	.7529	.7471	.7414	.7358	.7302
7	.7246	.7190	.7136	.7081	.7027	.6973
8	.6920	.6867	.6815	.6762	.6711	.6659
9	.6609	.6558	.6508	.6458	.6409	.6360
10	.6311	.6263	.6215	.6167	.6121	.6074
11	.6027	.5981	.5936	.5890	.5845	.5801
12	.5756	.5712	.5668	.5625	.5582	.5539
13	.5497	.5455	.5413	.5372	.5331	.5290
14	.5250	.5210	.5170	.5130	.5092	.5053
15	.5014	.4975	.4938	.4900	.4862	.4825
16	.4788	.4752	.4715	.4679	.4644	.4608
17	.4573	.4538	.4503	.4469	.4435	.4401
18	.4367	.4334	.4301	.4268	.4235	.4203
19	.4171	.4139	.4107	.4076	.4045	.4014
20	.3983	.3953	.3922	.3893	.3863	.3833
21	.3804	.3775	.3746	.3717	.3689	.3661
22	.3633	.3605	.3578	.3550	.3523	.3496
23	.3469	.3443	.3417	.3391	.3365	.3339
24	.3313	.3288	.3263	.3238	.3213	.3189
25	.3164	.3140	.3116	.3092	.3069	.3045
26	.3022	.2999	.2976	.2953	.2931	.2908
27	.2886	.2864	.2842	.2820	.2799	.2777
28	.2756	.2735	.2714	.2694	.2673	.2652
29	.2632	.2612	.2592	.2572	.2553	.2533
30	.2514	.2495	.2476	.2457	.2438	.2419
31	.2401	.2382	.2364	.2346	.2328	.2310
32	.2293	.2275	.2258	.2241	.2224	.2206
33	.2190	.2173	.2156	.2140	.2124	.2107
34	.2091		.2059		.2028	
35	.1997		.1967		.1937	
36	.1907		.1878		.1850	
37	.1821		.1794		.1766	
38	.1739		.1713		.1687	
39	.1661		.1636		.1611	

SODIUM - 24

Minutes Hours	0	10	20	30	40	50
40	.1587		.1562		.1539	
41	.1515		.1492		.1469	
42	.1447		.1425		.1403	
43	.1382		.1361		.1340	
44	.1320		.1300		.1280	
45	.1260		.1241		.1222	
46	.1204		.1185		.1167	
47	.1150		.1132		.1115	
48	.1098		.1081		.1065	
49	.1048		.1033		.1017	

STRONTIUM - 89

λ factor (½ day) = 0.00654

$T_{\frac{1}{2}}$ = 53 days

Days	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
0	-----	.9935	.9870	.9806	.9742	.9678	.9615	.9552	.9490	.9428	.9367	.9306
6	.9245	.9185	.9125	.9066	.9007	.8948	.8890	.8832	.8774	.8717	.8660	.8603
12	.8547	.8492	.8436	.8381	.8327	.8272	.8218	.8165	.8112	.8059	.8006	.7954
18	.7902	.7851	.7800	.7749	.7698	.7648	.7598	.7549	.7500	.7451	.7402	.7354
24	.7306	.7258	.7211	.7164	.7117	.7071	.7025	.6979	.6933	.6888	.6843	.6799
30	.6754	.6710	.6667	.6623	.6580	.6537	.6494	.6452	.6410	.6368	.6327	.6286
36	.6245	.6204	.6164	.6123	.6083	.6044	.6004	.5965	.5926	.5888	.5849	.5811
42	.5773	.5736	.5698	.5661	.5624	.5587	.5551	.5515	.5479	.5443	.5408	.5372
48	.5337	.5303	.5268	.5234	.5200	.5166	.5132	.5099	.5065	.5032	.5000	.4967
54	.4935	.4902	.4870	.4839	.4807	.4776	.4745	.4714	.4683	.4653	.4622	.4592
60	.4562	.4532	.4503	.4473	.4444	.4415	.4387	.4358	.4330	.4301	.4273	.4245
66	.4218	.4190	.4163	.6136	.4109	.4082	.4055	.4029	.4003	.3977	.3951	.3925
72	.3899		.3849		.3799		.3749		.3701		.3653	
78	.3605		.3558		.3512		.3466		.3421		.3377	
84	.3333		.3290		.3247		.3205		.3163		.3122	
90	.3081		.3041		.3002		.2963		.2924		.2886	
96	.2849		.2812		.2775		.2739		.2704		.2669	
102	.2634		.2600		.2566		.2533		.2500		.2467	
108	.2435		.2403		.2372		.2341		.2311		.2281	
114	.2251		.2222		.2193		.2165		.2137		.2109	
120	.2081		.2054		.2028		.2001		.1975		.1950	
126	.1924				.1875				.1826			
132	.1779				.1733				.1688			
138	.1645				.1602				.1561			
144	.1521				.1481				.1443			
150	.1406				.1369				.1334			
156	.1300				.1266				.1233			
162	.1202				.1171				.1140			
168	.1111				.1082				.1054			
174	.1027				.1000							

STRONTIUM - 90

λ factor (0.5 years) = 0.017416

$T_{\frac{1}{2}}$ = 19.9 years

Years	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-----	.9828	.9658	.9491	.9327	.9166	.9008	.8852	.8700	.8550
5	.8401	.8256	.8114	.7974	.7836	.7701	.7568	.7437	.7309	.7183
10	.7059	.6937	.6817	.6699	.6584	.6470	.6358	.6249	.6141	.6034
15	.5930	.5828	.5728	.5629	.5532	.5436	.5342	.5250	.5159	.5070
20	.4983	.4897	.4812	.4729	.4647	.4567	.4488	.4411	.4334	.4260
25	.4186	.4114	.4043	.3973	.3904	.3837	.3771	.3706	.3642	.3579
30	.3517	.3456	.3397	.3338	.3280	.3224	.3168	.3113	.3060	.3007
35	.2955	.2904	.2854	.2804	.2756	.2708	.2662	.2616	.2571	.2526
40	.2483		.2398		.2316		.2236		.2160	
45	.2086		.2014		.1945		.1879		.1814	
50	.1752									

SULFUR - 35

λ factor (0.5 days) = 0.003979

$T_{\frac{1}{2}}$ = 87.1 days

Days	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-----	.9960	.9920	.9882	.9842	.9803	.9764	.9725	.9687	.9648
5	.9610	.9571	.9534	.9496	.9458	.9420	.9383	.9346	.9309	.9272
10	.9235	.9198	.9162	.9126	.9089	.9053	.9017	.8982	.8946	.8910
15	.8875	.8839	.8805	.8770	.8735	.8700	.8666	.8631	.8597	.8562
20	.8528	.8495	.8461	.8427	.8394	.8360	.8328	.8294	.8261	.8228
25	.8195	.8164	.8131	.8099	.8066	.8035	.8003	.7971	.7939	.7907
30	.7877	.7845	.7814	.7783	.7751	.7721	.7690	.7660	.7629	.7599
35	.7569	.7539	.7509	.7479	.7450	.7420	.7390	.7361	.7332	.7303
40	.7274	.7245	.7216	.7187	.7159	.7131	.7102	.7074	.7045	.7018
45	.6990	.6962	.6934	.6907	.6880	.6852	.6825	.6798	.6771	.6744
50	.6717	.6690	.6664	.6638	.6611	.6585	.6559	.6532	.6507	.6481
55	.6455	.6429	.6404	.6379	.6353	.6328	.6303	.6278	.6253	.6228
60	.6203	.6179	.6155	.6130	.6105	.6081	.6057	.6033	.6009	.5985
65	.5961	.5937	.5914	.5891	.5867	.5844	.5820	.5798	.5775	.5752
70	.5729	.5706	.5684	.5661	.5638	.5616	.5594	.5572	.5549	.5527
75	.5505	.5484	.5462	.5440	.5418	.5397	.5376	.5354	.5333	.5312
80	.5291	.5270	.5249	.5228	.5207	.5187	.5166	.5145	.5125	.5104
85	.5084	.5064	.5044	.5024	.5004	.4984	.4964	.4945	.4925	.4906
90	.4886	.4867	.4847	.4828	.4809	.4790	.4771	.4752	.4733	.4714
95	.4695	.4677	.4658	.4639	.4621	.4603	.4585	.4566	.4548	.4530
100	.4512	.4494	.4476	.4459	.4441	.4423	.4406	.4388	.4371	.4354
105	.4336	.4319	.4302	.4285	.4268	.4251	.4234	.4217	.4200	.4184
110	.4167	.4150	.4134	.4118	.4101	.4085	.4069	.4053	.4037	.4020
115	.4004	.3988	.3973	.3957	.3941	.3925	.3910	.3895	.3879	.3864
120	.3848	.3833	.3818	.3803	.3784	.3772	.3758	.3743	.3728	.3713
125	.3698	.3684	.3669	.3654	.3640	.3525	.3611	.3597	.3582	.3568
130	.3554	.3540	.3526	.3512	.3498	.3484	.3470	.3456	.3442	.3429
135	.3415	.3402	.3388	.3375	.3361	.3348	.3335	.3321	.3309	.3295
140	.3282	.3269	.3256	.3243	.3230	.3217	.3205	.3192	.3179	.3166
145	.3154	.3141	.3129	.3116	.3104	.3092	.3080	.3067	.3055	.3043
150	.3031		.3007		.2983		.2959		.2936	
155	.2913		.2890		.2867		.2844		.2822	
160	.2799		.2777		.2755		.2733		.2711	
165	.2690		.2669		.2647		.2626		.2606	
170	.2585		.2565		.2544		.2524		.2504	
175	.2484		.2464		.2445		.2426		.2406	
180	.2387		.2368		.2349		.2331		.2312	
185	.2294		.2276		.2258		.2240		.2222	
190	.2205		.2187		.2170		.2153		.2135	
195	.2119		.2102		.2085		.2069		.2052	

THALLIUM - 204

λ factor (20 days) = 0.01085

$T_{\frac{1}{2}}$ = 3.5 years

Days	0	20	40	60	80
0	-----	.9892	.9785	.9679	.9575
100	.9471	.9370	.9268	.9169	.9069
200	.8972	.8875	.8779	.8684	.8591
300	.8498	.8406	.8315	.8226	.8137
400	.8049	.7962	.7877	.7791	.7707
500	.7624	.7542	.7460	.7380	.7300
600	.7222	.7143	.7067	.6990	.6914
700	.6840	.6766	.6693	.6621	.6549
800	.6478	.6409	.6339	.6271	.6203
900	.6137	.6070	.6005	.5940	.5876
1000	.5812	.5750	.5688	.5626	.5565
1100	.5506	.5446	.5388	.5329	.5272
1200	.5215	.5158	.5103	.5047	.4993
1300	.4939	.4886	.4833	.4781	.4729
1400	.4679	.4628	.4578	.4528	.4480
1500	.4431	.4384	.4336	.4290	.4243
1600	.4197	.4152	.4107	.4063	.4019
1700	.3976	.3933	.3890	.3849	.3807
1800	.3766	.3725	.3685	.3645	.3606
1900	.3567	.3528	.3490	.3452	.3415
2000	.3378	.3342	.3306	.3270	.3235
2100	.3200	.3165	.3131	.3097	.3064
2200	.3031	.2998	.2966	.2934	.2902
2300	.2871	.2840	.2809	.2779	.2749
2400	.2719				
2500	.2576				
2600	.2440				
2700	.2311				
2800	.2189				
2900	.2073				
3000	.1964				
3100	.1860				
3200	.1762				
3300	.1669				
3400	.1581				
3500	.1497				
3600	.1418				

YTTRIUM - 90

YTTRIUM - 91

λ factor (0.5 hours)(Y^{90})
(0.5 days (Y^{91}) = 0.00568

$T_{\frac{1}{2}}$ (Y^{90}) = 61 hours
(Y^{91}) = 61 days

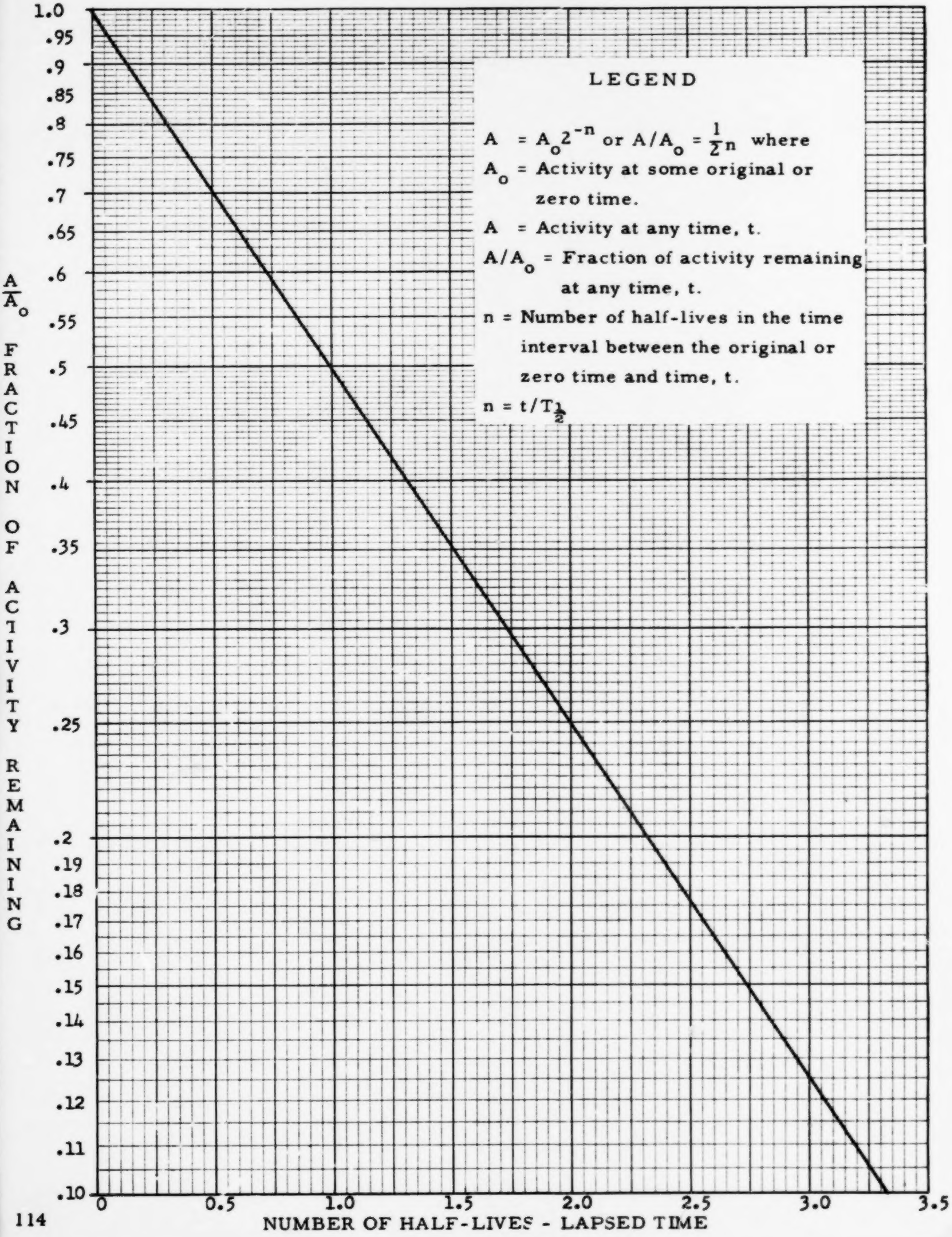
Hours (Y^{90}) Days (Y^{91})	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
0	-----	.9943	.9887	.9831	.9776	.9720	.9665	.9610	.9555	.9502
5	.9448	.9394	.9341	.9288	.9236	.9183	.9131	.9079	.9028	.8977
10	.8926	.8875	.8825	.8775	.8725	.8676	.8627	.8578	.8529	.8481
15	.8433	.8385	.8338	.8290	.8243	.8196	.8151	.8104	.8058	.8012
20	.7967	.7922	.7877	.7833	.7788	.7744	.7700	.7657	.7613	.7570
25	.7527	.7484	.7442	.7400	.7358	.7316	.7275	.7234	.7193	.7152
30	.7111	.7071	.7031	.6991	.6952	.6912	.6873	.6834	.6796	.6757
35	.6719	.6680	.6642	.6605	.6568	.6531	.6493	.6456	.6420	.6384
40	.6348	.6312	.6276	.6240	.6205	.6170	.6135	.6100	.6065	.6031
45	.5997	.5963	.5929	.5895	.5862	.5829	.5796	.5763	.5730	.5698
50	.5666	.5634	.5602	.5570	.5538	.5507	.5476	.5445	.5414	.5383
55	.5353	.5322	.5292	.5262	.5232	.5203	.5173	.5144	.5115	.5086
60	.5057	.5028	.5000	.4972	.4944	.4915	.4888	.4860	.4833	.4805
65	.4778	.4751	.4724	.4697	.4671	.4644	.4618	.4591	.4565	.4540
70	.4514	.4488	.4463	.4437	.4413	.4388	.4353	.4338	.4313	.4289
75	.4265	.4241	.4216	.4192	.4169	.4145	.4122	.4098	.4075	.4052
80	.4029	.4006	.3984	.3961	.3938	.3916	.3894	.3872	.3850	.3828
85	.3806	.3785	.3764	.3742	.3721	.3700	.3679	.3658	.3637	.3617
90	.3596	.3576	.3556	.3536	.3516	.3496	.3476	.3456	.3437	.3417
95	.3398	.3378	.3359	.3340	.3321	.3303	.3284	.3265	.3247	.3228
100	.3210	.3192	.3174	.3156	.3138	.3120	.3102	.3085	.3067	.3050
105	.3033	.3016	.2998	.2981	.2964	.2948	.2931	.2914	.2898	.2881
110	.2865	.2849	.2833	.2817	.2801	.2785	.2769	.2754	.2738	.2722
115	.2707	.2692	.2676	.2661	.2646	.2631	.2616	.2601	.2587	.2572
120	.2557	.2543	.2529	.2514	.2500	.2486	.2472	.2458	.2444	.2430
125	.2416		.2389		.2362		.2335		.2309	
130	.2283		.2257		.2232		.2206		.2181	
135	.2157		.2132		.2108		.2084		.2061	
140	.2038		.2015		.1992		.1969		.1947	
145	.1925		.1903		.1882		.1861		.1839	
150	.1819		.1798		.1778		.1758		.1738	
155	.1718		.1699		.1680		.1661		.1642	
160	.1623		.1605		.1587		.1569		.1551	
165	.1534		.1516		.1499		.1482		.1465	
170	.1449		.1433		.1416		.1400		.1385	
175	.1369		.1353		.1338		.1323		.1308	

ZINC - 65

λ factor (2 days) = 0.005545 $T_{\frac{1}{2}}$ = 250 days

Days	0	2	4	6	8	10	12	14	16	18
0	-----	.9945	.9890	.9835	.9781	.9727	.9673	.9619	.9566	.9513
20	.9461	.9408	.9356	.9304	.9253	.9202	.9151	.9100	.9050	.9000
40	.8950	.8901	.8852	.8803	.8754	.8706	.8658	.8610	.8562	.8514
60	.8467	.8421	.8374	.8328	.8282	.8236	.8190	.8145	.8100	.8055
80	.8011	.7966	.7922	.7879	.7835	.7792	.7749	.7706	.7663	.7621
100	.7579	.7537	.7495	.7454	.7412	.7371	.7330	.7290	.7250	.7210
120	.7170	.7130	.7091	.7051	.7012	.6973	.6935	.6897	.6859	.6821
140	.6783	.6746	.6708	.6671	.6634	.6597	.6561	.6525	.6489	.6453
160	.6417	.6382	.6346	.6311	.6276	.6242	.6208	.6173	.6139	.6105
180	.6071	.6038	.6004	.5971	.5938	.5905	.5872	.5840	.5808	.5776
200	.5744	.5712	.5680	.5649	.5618	.5587	.5556	.5525	.5494	.5464
220	.5434	.5403	.5374	.5344	.5314	.5285	.5256	.5227	.5198	.5169
240	.5141	.5112	.5084	.5056	.5028	.5000	.4972	.4945	.4918	.4890
260	.4863	.4836	.4810	.4783	.4757	.4730	.4704	.4678	.4652	.4627
280	.4601	.4576	.4550	.4525	.4500	.4475	.4450	.4426	.4401	.4377
300	.4353	.4329	.4305	.4281	.4257	.4234	.4210	.4187	.4164	.4141
320	.4118	.4095	.4073	.4050	.4028	.4005	.3983	.3961	.3939	.3918
340	.3896	.3874	.3853	.3832	.3810	.3789	.3768	.3747	.3727	.3706
360	.3686	.3665	.3645	.3625	.3605	.3585	.3565	.3545	.3526	.3506
380	.3487	.3468	.3449	.3430	.3411	.3392	.3373	.3354	.3336	.3317
400	.3299	.3281	.3263	.3245	.3227	.3209	.3191	.3173	.3156	.3138
420	.3121	.3104	.3087	.3070	.3053	.3036	.3019	.3002	.2986	.2969
440	.2953	.2936	.2920	.2904	.2888	.2872	.2856	.2840	.2824	.2809
460	.2793	.2778	.2763	.2747	.2732	.2717	.2702	.2687	.2672	.2657
480	.2643	.2628	.2613	.2599	.2585	.2570	.2556	.2542	.2528	.2514
500	.2500		.2473		.2445		.2418		.2392	
520	.2365		.2339		.2313		.2288		.2263	
540	.2238		.2213		.2188		.2164		.2141	
560	.2117		.2094		.2071		.2048		.2025	
580	.2003		.1981		.1959		.1937		.1916	
600	.1895		.1874		.1853		.1833		.1813	
620	.1793		.1773		.1753		.1734		.1715	
640	.1696		.1677		.1659		.1640		.1622	
660	.1604		.1587		.1569		.1552		.1535	
680	.1518		.1501		.1485		.1468		.1452	
700	.1436		.1420		.1404		.1389		.1374	
720	.1359		.1344		.1329		.1314		.1300	
740	.1285		.1271		.1257		.1243		.1229	
760	.1216		.1202		.1189		.1176		.1163	
780	.1150		.1138		.1125		.1113		.1100	
800	.1088		.1076		.1064		.1053		.1041	
820	.1030		.1018		.1007		.0996			

RADIOACTIVE DECAY, SEMI-LOG PLOT



LEGEND

$A = A_o 2^{-n}$ or $A/A_o = \frac{1}{2^n}$ where

A_o = Activity at some original or zero time.

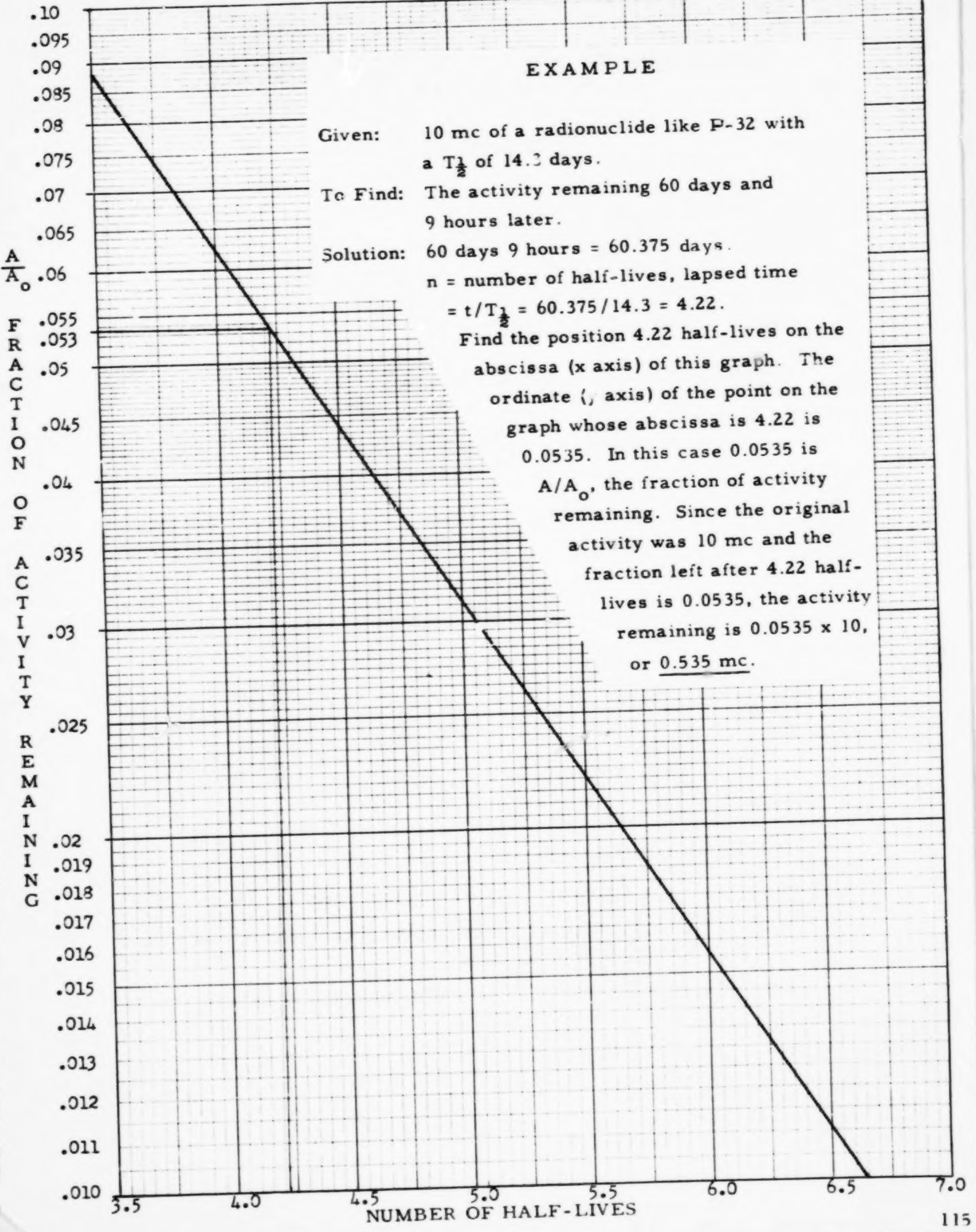
A = Activity at any time, t.

A/A_o = Fraction of activity remaining at any time, t.

n = Number of half-lives in the time interval between the original or zero time and time, t.

$n = t/T_{\frac{1}{2}}$

RADIOACTIVE DECAY, SEMI-LOG PLOT



EXAMPLE

Given: 10 mc of a radionuclide like P-32 with a $T_{\frac{1}{2}}$ of 14.3 days.

To Find: The activity remaining 60 days and 9 hours later.

Solution: 60 days 9 hours = 60.375 days.

n = number of half-lives, lapsed time $= t/T_{\frac{1}{2}} = 60.375/14.3 = 4.22$.

Find the position 4.22 half-lives on the abscissa (x axis) of this graph. The ordinate (y axis) of the point on the graph whose abscissa is 4.22 is 0.0535. In this case 0.0535 is A/A_o, the fraction of activity remaining. Since the original activity was 10 mc and the fraction left after 4.22 half-lives is 0.0535, the activity remaining is 0.0535 x 10, or 0.535 mc.

NOMOGRAPHS FOR RADIOACTIVE DECAY CORRECTION

(See Pages 117 and 118)

EXAMPLES OF USE

Example 1:

Given: UNKNOWN Radioisotope
Initial Activity, A_o = 10,972 dpm.
Final Activity, A_t = 2,743 dpm.
Decay time, t = 62 hours

Find: Half-life, $T_{\frac{1}{2}}$, in days

Solution: $K = \frac{A_o}{A_t} = \frac{10,972}{2,743} = 4.0$

In order to enter the nomograph, t = 62 hours must be converted to a handier number, so divide t = 62 hours by 4. Then $\frac{t}{4} = \frac{62}{4} = 15.5$ four-hour periods.

Using straightedge, connect K = 4.0 with t = 15.5 and read $T_{\frac{1}{2}}$ = 7.75 four-hour periods, or $T_{\frac{1}{2}} = 4 \times 7.75 = 31.0$ hours.

$T_{\frac{1}{2}} = 31.0 \text{ hours} = \frac{31.0}{24} = 1.29$ days, half-life of unknown radioisotope

Example 2:

Given: Na^{24}
Half-life, $T_{\frac{1}{2}}$ = 14.9 hours
Decay time, t = 2.0 days
Final Activity, A_t = 62 dpm.

Find: Initial Activity, A_o

Solution: $T_{\frac{1}{2}}$ = 14.9 hours

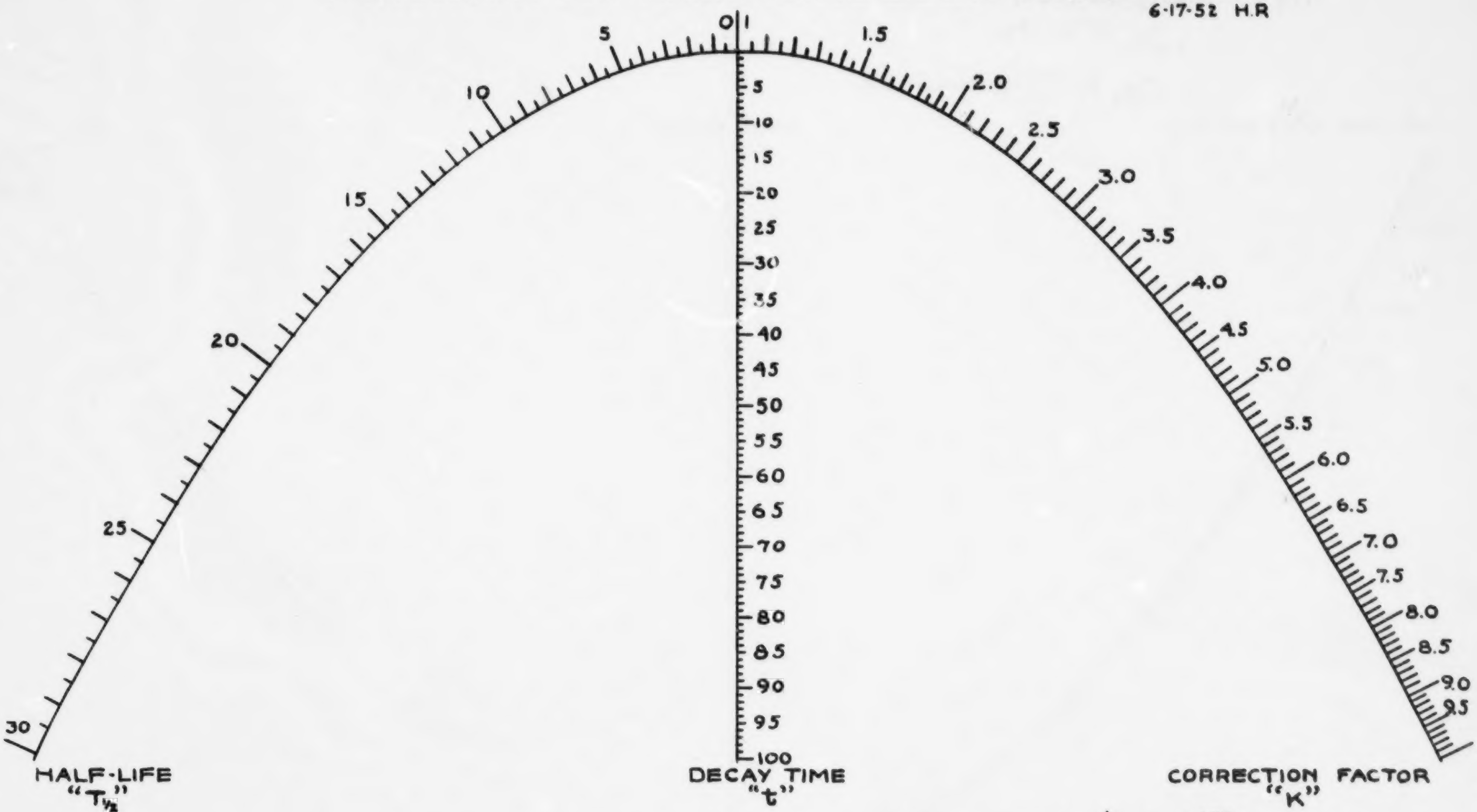
$t = 2.0 \text{ days} = 2.0 \times 24 = 48.0$ hours

Using straightedge, connect $T_{\frac{1}{2}}$ = 14.9 with t = 48.0, and read K = 9.32

Then: $A_o = KA_t = 9.32 \times 62 = 578$ dpm., Initial Activity

NOMOGRAPH FOR RADIOACTIVE DECAY CORRECTION.

6-17-52 H.R


0
1
5
10
15
20
25
30
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
HALF-LIFE
"$T_{1/2}$"
DECAY TIME
"t"
CORRECTION FACTOR
"K"

EQUATION: $K = \frac{A_0}{A_t} = e^{\frac{0.693}{T_{1/2}}t}$

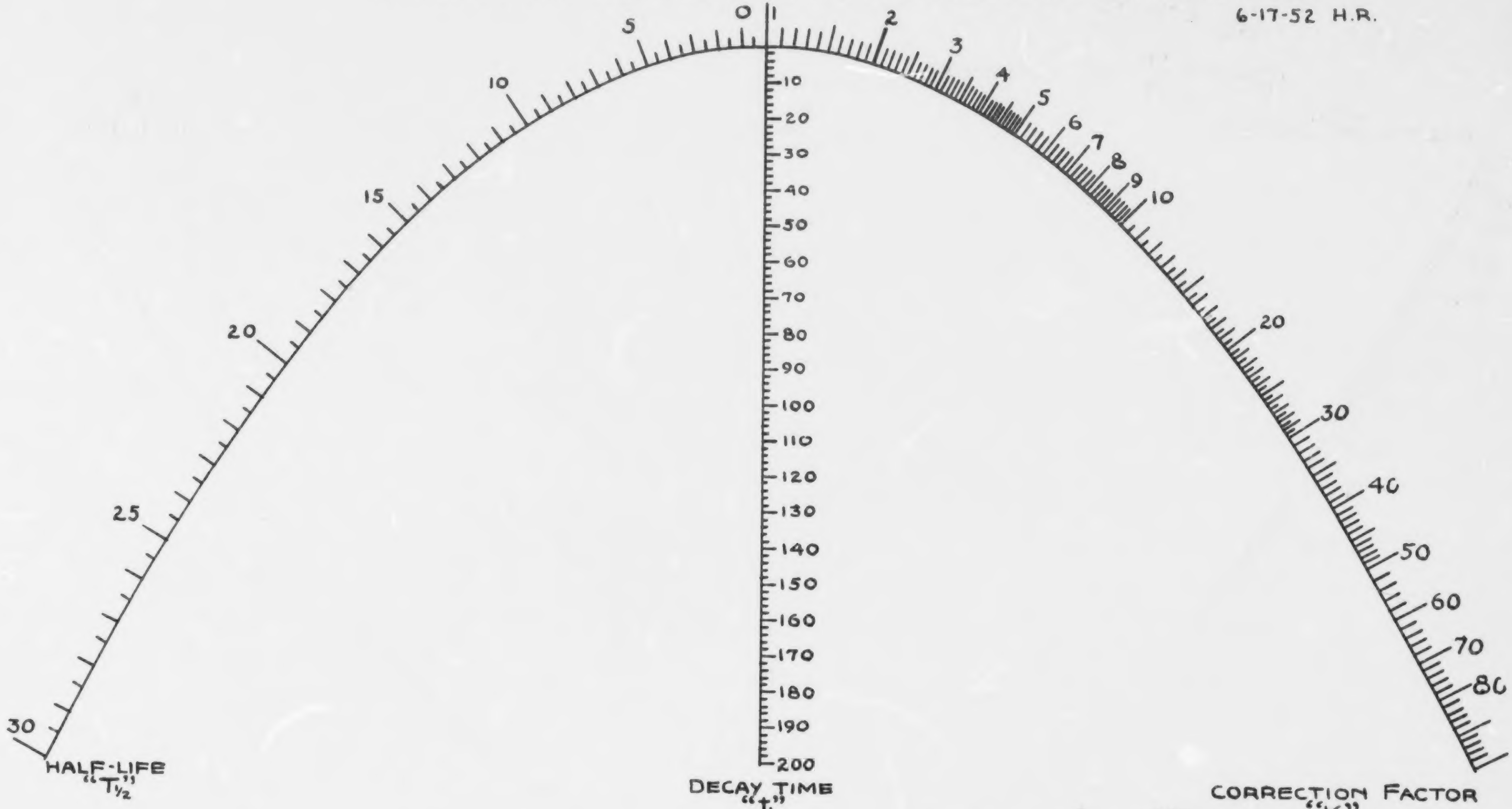
$A_t = A_0 e^{-\frac{0.693}{T_{1/2}}t}$

A_0 = INITIAL ACTIVITY, $t = 0$

A_t = ACTIVITY AFTER TIME t.

NOMOGRAPH FOR RADIOACTIVE DECAY CORRECTION.

6-17-52 H.R.



EQUATION: $K = \frac{A_0}{A_t} = e^{\frac{0.693}{T_{1/2}} t}$

$A_t = A_0 e^{-\frac{0.693}{T_{1/2}} t}$

A_0 = INITIAL ACTIVITY, $t = 0$.

A_t = ACTIVITY AFTER TIME t.

THORIUM SERIES

(4n)*

Radioelement	Historical Name	Symbol	Half Life	Radiation Type & Energy**
Thorium	Thorium	$_{90}Th^{232}$	1.39×10^{10}y	α-3.98 γ-~0.055
Radium	Mesothorium I	$_{88}Ra^{228}$(MsTh$_1$)	6.7y	β-~0.012 γ-~0.03
Actinium	Mesothorium II	$_{89}Ac^{228}$(MsTh$_2$)	6.13h	β-2.18 γ-0.058
Thorium	Radiothorium	$_{90}Th^{228}$(RdTh)	1.90y	α-5.423 γ-0.0843
Radium	Thorium X	$_{88}Ra^{224}$(ThX)	3.64d	α-5.681 γ-0.241
Radon	Thoron (Em)	$_{86}Rn^{220}$(Tn)	54.5s	α-6.282
Polonium ~100% 0.014%(?)	Thorium A	$_{84}Po^{216}$(ThA)	0.158s	α-6.774 β-(?)
Lead	Thorium B	$_{82}Pb^{212}$(ThB)	10.6h	β-0.355 γ-0.2386
Astatine-216	Astatine	$_{85}At^{216}$	3×10^{-4}s	α-7.79
Bismuth 66.3% 33.7%	Thorium C	$_{83}Bi^{212}$(ThC)	60.5m	α-6.086 β-2.250 γ-0.40 γ-2.20
Polonium	Thorium C'	$_{84}Po^{212}$(ThC')	3.04×10^{-7}s	α-8.776
Thallium	Thorium C''	$_{81}Tl^{208}$(ThC'')	3.1m	β-1.792 γ-2.62
Lead (End Product)	Thorium D	$_{82}Pb^{208}$(ThD)	Stable (52.3% abundance)	

---

* An expression in which "n" is an integer; the expression describes the mass number of any number within that series. Example:

$$_{90}Th^{232} \quad (4n) \ldots\ldots\ldots\ldots 4(58) = 232$$

** Energy is expressed in Mev.

NEPTUNIUM SERIES

(4n + 1)*

Radioelement	Symbol	Half Life	Energy of Radiation (Mev)		
			α	β	γ
Plutonium	${}_{94}Pu^{241}$	14y	4.91	0.021	0.100
Americium	${}_{95}Am^{241}$	470y	5.546	....	0.0597
Neptunium	${}_{93}Np^{237}$	2.20×10^{6}y	4.77	....	....
Protactinium	${}_{91}Pa^{233}$	27.4d	....	0.530	0.029
Uranium	${}_{92}U^{233}$	1.62×10^{5}y	4.823	....	0.428
Thorium	${}_{90}Th^{229}$	7340y	5.02	....	....
Radium	${}_{88}Ra^{225}$	14.8d	....	0.31	....
Actinium	${}_{89}Ac^{225}$	10.0d	5.80	....	....
Francium	${}_{87}Fr^{221}$	4.8m	6.30	....	0.220
Astatine	${}_{85}At^{217}$	0.018s	7.02	....	....
Bismuth 96% 4%	${}_{83}Bi^{213}$	47m	5.86	1.39	0.434
Polonium	${}_{84}Po^{213}$	4.2×10^{-6}s	8.336	....	....
Thallium	${}_{81}Tl^{209}$	2.2m	....	1.99	0.12
Lead	${}_{82}Pb^{209}$	3.22h	....	0.635	....
Bismuth (End Product)	${}_{83}Bi^{209}$	Stable (100% abundance)	....	....	....

---

* An expression in which "n" is an integer; the expression describes the mass number of any member within that series. Example:

$${}_{90}Th^{229} \quad (4n + 1) \, . \, . \, . \, . \, . \, . \, . \, . \, . \, . \, 4(57) + 1 = 229$$

URANIUM SERIES

(4n + 2)*

Radioelement	Historical Name	Symbol	Half Life	Radiation Type & Energy**
Uranium	Uranium I	$_{92}U^{238}$(UI)	4.49×10^{9}y	α-4.18 γ-~0.045
Thorium	Uranium X_1	$_{90}Th^{234}$(UX_1)	24.10d	β-0.205 γ-0.09
Protactinium	Uranium X_2	$_{91}Pa^{234}$(UX_2)	1.175m	β-2.32 γ-0.817
Uranium	Uranium II	$_{92}U^{234}$(UII)	2.48×10^{5}y	α-4.763 γ-0.050
Thorium	Ionium	$_{90}Th^{230}$(Io)	8.0×10^{4}y	α-4.682 γ-0.068
Radium	Radium	$_{88}Ra^{226}$	1622y	α-4.777 γ-0.186
Radon	Ra Emanation	$_{86}Rn^{222}$	3.825d	α-5.486
Polonium 99.96% 0.04%	Radium A	$_{84}Po^{218}$(RaA)	3.05m	α-5.998 β^-
Lead	Radium B	$_{82}Pb^{214}$(RaB)	26.8m	β-0.65 γ-0.05323
Astatine-218	Astatine	$_{85}At^{218}$	1.5-2s	α-6.63
Bismuth 99.96% 0.04%	Radium C	$_{83}Bi^{214}$(RaC)	19.7m	α-5.505 β-3.17 γ-0.6094
Polonium	Radium C'	$_{84}Po^{214}$(RaC')	1.637×10^{-4}s	α-7.680
Thallium	Radium C''	$_{81}Tl^{210}$(RaC'')	1.32m	β-1.8 γ->2.8
Lead	Radium D	$_{82}Pb^{210}$(RaD)	22y	β-0.018 γ-0.0465
Bismuth ~100% ~10^{-5}%	Radium E	$_{83}Bi^{210}$(RaE)	5.02d	β-1.17
Polonium	Radium F	$_{84}Po^{210}$(RaF)	138.3d	α-5.0298 γ-0.800
Thallium-206	Thallium	$_{81}Tl^{206}$	4.19m	β-1.51
Lead (End Product)	Radium G	$_{82}Pb^{206}$(RaG)	Stable 23.6% abundance	-

---

* An expression in which "n" is an integer; the expression describes the mass number of any member within that series. Example:

$_{82}Pb^{206}$ (4n + 2) . . . . 4(51) + 2 = 206

** Energy is expressed in Mev.

ACTINIUM SERIES

(4n + 3)*

Radioelement	Historical Name	Symbol	Half Life	Radiation Type & Energy**
Uranium	Actinouranium	${}_{92}U^{235}$(AcU)	7.13×10^{8}y	α-4.58 γ-0.094
Thorium	Actinium Y	${}_{90}Th^{231}$(UY)	25.64h	β-0.302 γ-0.022
Protactinium	Protoactinium	${}_{91}Pa^{231}$	3.43×10^{4}y	α-5.042 γ-0.034
Actinium 98.8% 1.2%	Actinium	${}_{89}Ac^{227}$	22.0y	α-4.942 β-0.04 γ-0.037
Thorium	Radioactinium	${}_{90}Th^{227}$(RdAc)	18.6d	α-6.030 γ-0.050
Francium	Actinium K	${}_{87}Fr^{223}$	21m	β-1.2
Radium	Actinium X	${}_{88}Ra^{223}$(AcX)	11.2d	α-5.860 γ-0.144
Radon	Actinon (Em)	${}_{86}Rn^{219}$(An)	3.92s	α-6.824 γ-0.067
Polonium ~100% ~5 x 10^{-4}%	Actinium A	${}_{84}Po^{215}$(AcA)	1.83×10^{-3}s	α-7.365
Lead	Actinium B	${}_{82}Pb^{211}$(AcB)	36.1m	β-1.39 γ-0.065
Astatine-215	Astatine	${}_{85}At^{215}$	~10^{-4}s	α-8.0
Bismuth 99.68% 0.32%	Actinium C	${}_{83}Bi^{211}$(AcC)	2.16m	α-6.618 β γ-0.350
Polonium	Actinium C'	${}_{84}Po^{211}$(AcC')	0.52s	α-7.434
Thallium	Actinium C''	${}_{81}Tl^{207}$(AcC'')	4.79m	β-1.44 γ-0.870
Lead (End Product)	Actinium D	${}_{82}Pb^{207}$(AcD)	Stable (22.6% abundance)	

---

* An expression in which "n" is an integer; the expression describes the mass number of any member within that series. Example:

$${}_{82}Pb^{207} \ (4n + 3) \ldots\ldots\ldots\ldots\ 4(51) + 3 = 207$$

** Energy is expressed in Mev.

SECTION IV

Radiation Levels, from Gamma Emitters . . . . page 123
Total Mass Absorption Coefficients . . . . " 124-126
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Dose Build Up Factor for
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CALCULATED GAMMA RADIATION LEVELS FOR ONE CURIE OF SOME RADIOISOTOPES

Isotopes	Quantum Energy (E) in Mev.						I_γ at 1 yard r/hr.	I_γ at 1 meter r/hr.
	Annihilation Radiation	Nuclear gamma radiation						
Na^{22}	0.51(2)	1.30(1)					1.54	1.29
Na^{24}		1.38(1)	2.76(1)				2.31	1.93
Mn^{52}	0.51(0.7)	0.73(1)	0.94(1)	1.46(1)			2.31	1.93
Mn^{54}		0.84(1)					0.579	0.485*
Fe^{59}		1.10(0.5)	1.30(0.5)				0.770	0.645
Co^{58}	0.51(0.3)	0.81(1)					0.665	0.556*
Co^{60}		1.17(1)	1.33(1)				1.59	1.33
Cu^{64}	0.51(0.38)						0.137	0.115
Zn^{65}	0.51(0.05)	1.12(0.44)					0.339	0.284*
As^{76}		0.56(0.48)	1.21(0.18)	1.77(0.02)	2.1(0.10)		0.467	0.391
I^{130}		0.417(0.4)	0.537(1)	0.667(1)	0.744(1)		1.48	1.24
I^{131}		0.08(.0075)	0.283(0.036)	0.364(0.855)	0.637(0.093)	0.722(0.028)	0.349	0.292
Cs^{137}		0.661(0.836)					0.387	0.324
Au^{198}		0.411(0.947)	0.673(0.005)	1.09(0.005)			0.282	0.236
Ra^{226}	and equilibrium decay products	12 principle lines, 0.188 to 2.2 Mev.					1.16 1.005**	0.97 0.84**

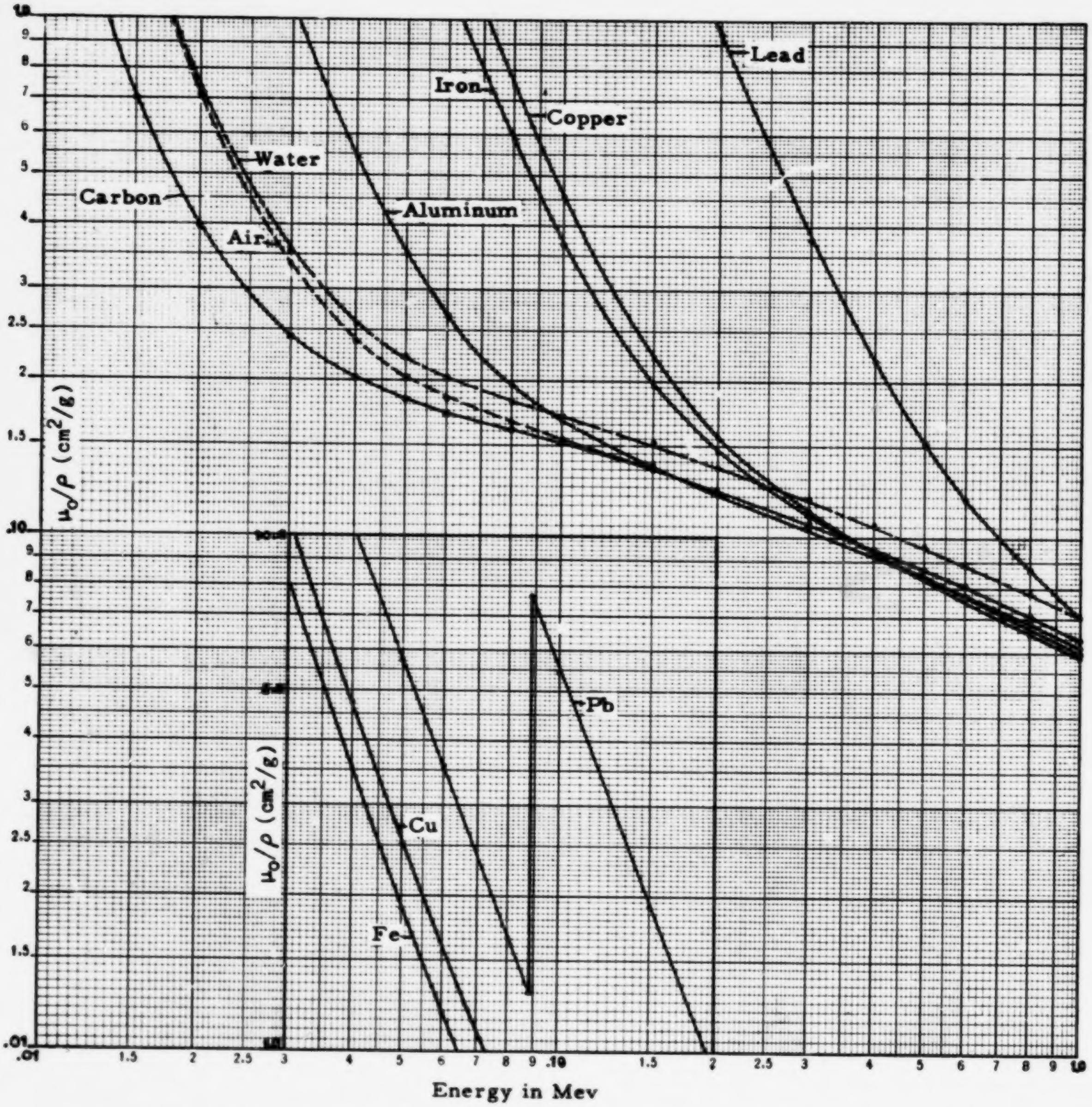
Gamma ray source strength was calculated using equation no. J(1), page 49.

It is assumed that all primary positron beta rays are absorbed within the source, hence 2 quanta of 0.51 Mev annihilation radiation are included for each positron beta ray per disintegration. The numbers in parentheses indicate the number of photons of the particular energy that are released per disintegration, corrected for internal conversion where it is significant. The absorption of the primary radiation in 1 meter of standard air is ignored. Isotopes marked with * in the I_γ column, have x-ray emission following electron capture whose contribution to I_γ is negligible at 1 meter, but would not be negligible at distances of the order of 1 cm. Self-absorption is ignored.

** With 0.5 mm Pt filtration. This figure is the average of the better measurements.

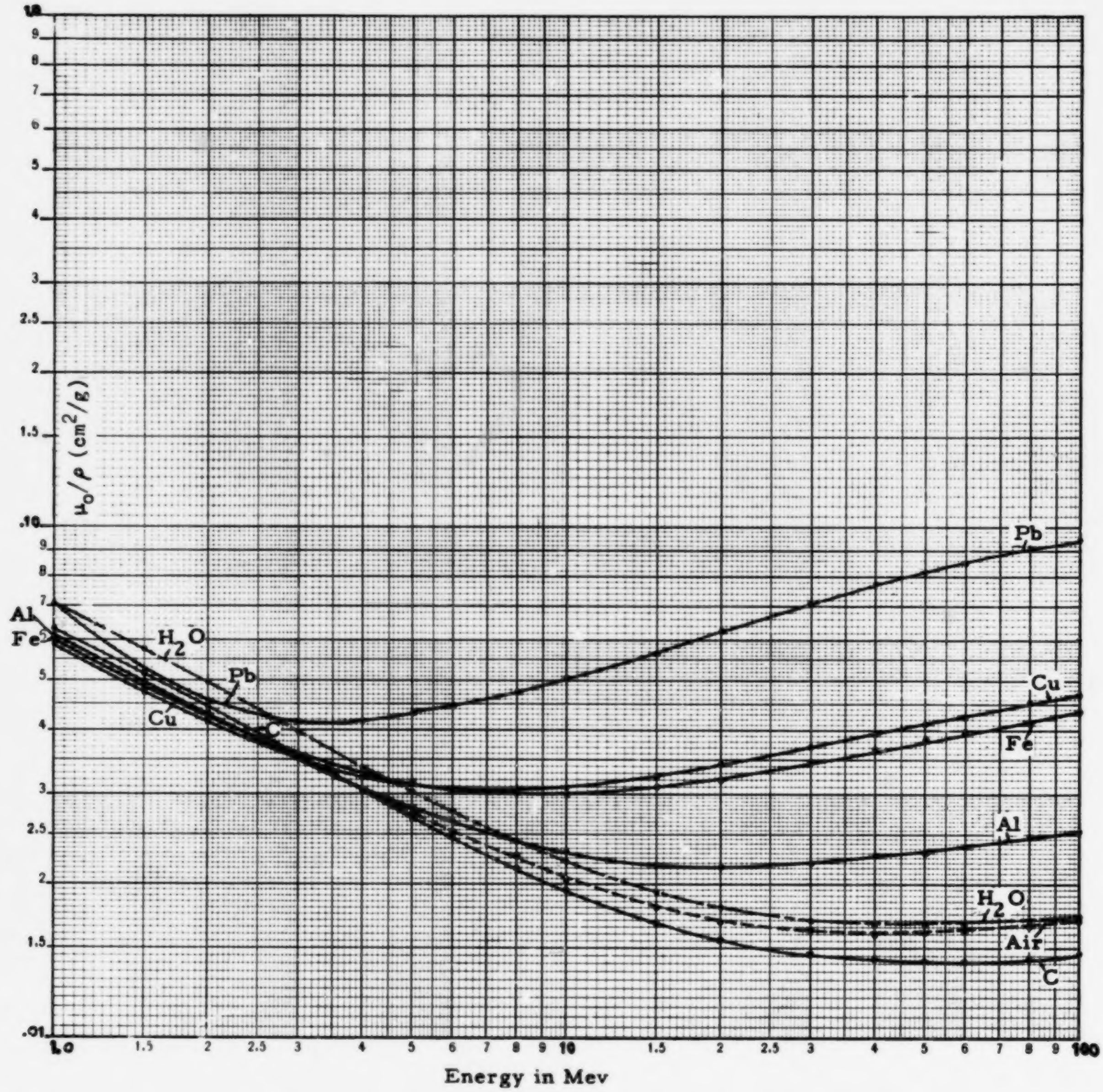
Decay scheme data was taken from the table of isotopes appended in this handbook.

TOTAL MASS ABSORPTION COEFFICIENTS FOR X- AND GAMMA RADIATION



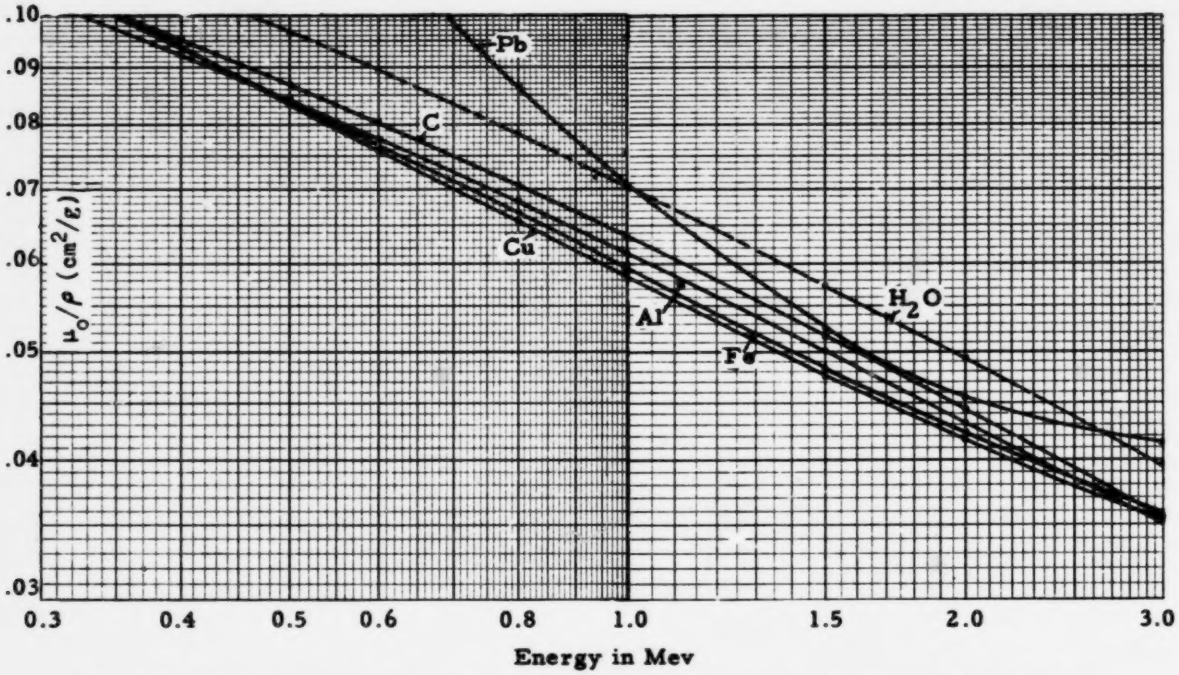
Data obtained from Gladys R. White, National Bureau of Standards. The total absorption coefficients for air in the range 0.3 to 3.0 Mev may be considered identical to those of carbon. Insert extends the range for lead, copper and iron.

TOTAL MASS ABSORPTION COEFFICIENTS FOR X- AND GAMMA RADIATION



Data obtained from Gladys R. White, National Bureau of Standards. The total absorption coefficients for air in the range 0.3 to 3.0 Mev may be considered identical to those of carbon.

TOTAL MASS ABSORPTION COEFFICIENTS FOR X- AND GAMMA RADIATION



Above graph is an expansion of the 0.3 to 3.0 Mev range of the graphs shown on the preceeding pages.

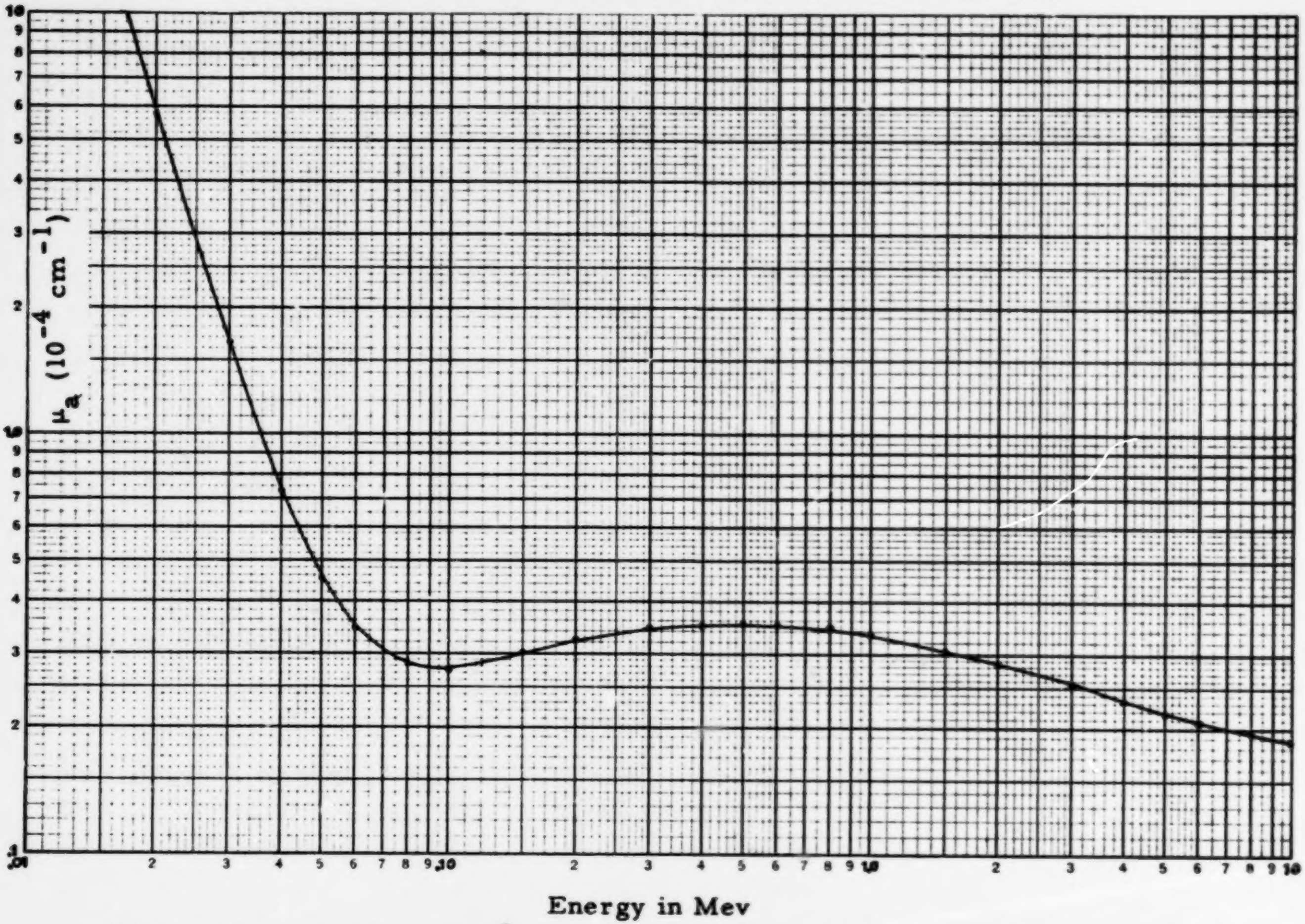
MASS ABSORPTION COEFFICIENTS FOR CONCRETE

(.56% H, 49.56% O, 31.35% Si, 4.56% Al, 8.26% Ca, 1.22% Fe, .24% Mg, 1.71% Na, 1.92%K, .12% S) Density - 2.35 g/cm^3.

Energy (Mev)	μ_o/ρ (cm^2/g)	Energy (Mev)	μ_o/ρ (cm^2/g)	Energy (Mev)	μ_o/ρ (cm^2/g)
.01	24.6	.30	.107	6.0	.0268
.015	7.68	.40	.0954	8.0	.0243
.02	3.34	.50	.0870	10.0	.0229
.03	1.10	.60	.0804	15	.0214
.04	.542	.80	.0706	20	.0209
.05	.350	1.0	.0635	30	.0209
.06	.267	1.5	.0517	40	.0213
.08	.197	2.0	.0445	50	.0217
.10	.169	3.0	.0363	60	.0222
.15	.139	4.0	.0317	80	.0230
.20	.124	5.0	.0287	100	.0237

Total mass absorption coefficient data obtained from Gladys R. White, National Bureau of Standards.

"TRUE" LINEAR ABSORPTION COEFFICIENTS FOR AIR*



* 78% N_2, 21% O_2, 1% A at 20°C. Data obtained from Gladys R. White, National Bureau of Standards.

Dose Build-up Factors for Lead, Iron, Aluminum and Water
(See Pages 128 and 129)

Build-up factors are from: H. Goldstein, J.E. Wilkins, Jr., S. Preiser, Interim Report of the NDA-NBS Calculations of Gamma Ray Penetration, NDA Memo 15C-20 (Nuclear Development Associates, White Plains, New York).

μ_0 is the linear absorption coefficient (expressed in units reciprocal to those of x) corresponding to the medium and the source energy under consideration and x is the linear depth of penetration. The designation "dose" indicates that the gamma-ray flux is to be measured in terms of roentgens, i.e., with the energy spectrum weighted in proportion to the energy absorption coefficient of air.

The accuracy of the results for Pb and Fe is estimated roughly at 5% except at the greatest penetration where the errors may be as large as 15%. The low-energy portion of the spectrum contributes disproportionately to the dose build-up factor for water and aluminum. Hence the limit of error for these materials is undoubtedly greater, probably being around 10% for medium penetrations, rising to 25-30% for the deepest penetration.

DOSE BUILD-UP FACTOR FOR PLANE MONODIRECTIONAL SOURCE*

E_o (Mev)	$\mu_o x$					
	1	2	4	7	10	15
IRON						
.5	2.07	2.94	4.87	8.31	12.4	20.6
1	1.92	2.74	4.57	7.81	11.6	18.9
2	1.69	2.35	3.76	6.11	8.78	13.7
3	1.58	2.13	3.32	5.26	7.41	11.4
4	1.48	1.90	2.95	4.61	6.46	9.92
6	1.35	1.71	2.48	3.81	5.35	8.39
8	1.27	1.55	2.17	3.27	4.58	7.33
10	1.22	1.44	1.95	2.89	4.07	6.70
LEAD						
.5	1.24	1.39	1.63	1.87	2.08	2.68
1	1.38	1.68	2.18	2.80	3.40	4.20
2	1.40	1.76	2.41	3.36	4.35	5.94
3	1.36	1.71	2.42	3.55	4.82	7.18
4	1.28	1.56	2.18	3.29	4.69	7.70
6	1.19	1.40	1.87	2.97	4.69	9.53
8	1.14	1.30	1.69	2.61	4.18	9.08
10	1.11	1.24	1.54	2.27	3.54	7.70

DOSE BUILD-UP FACTOR FOR POINT ISOTROPIC SOURCE

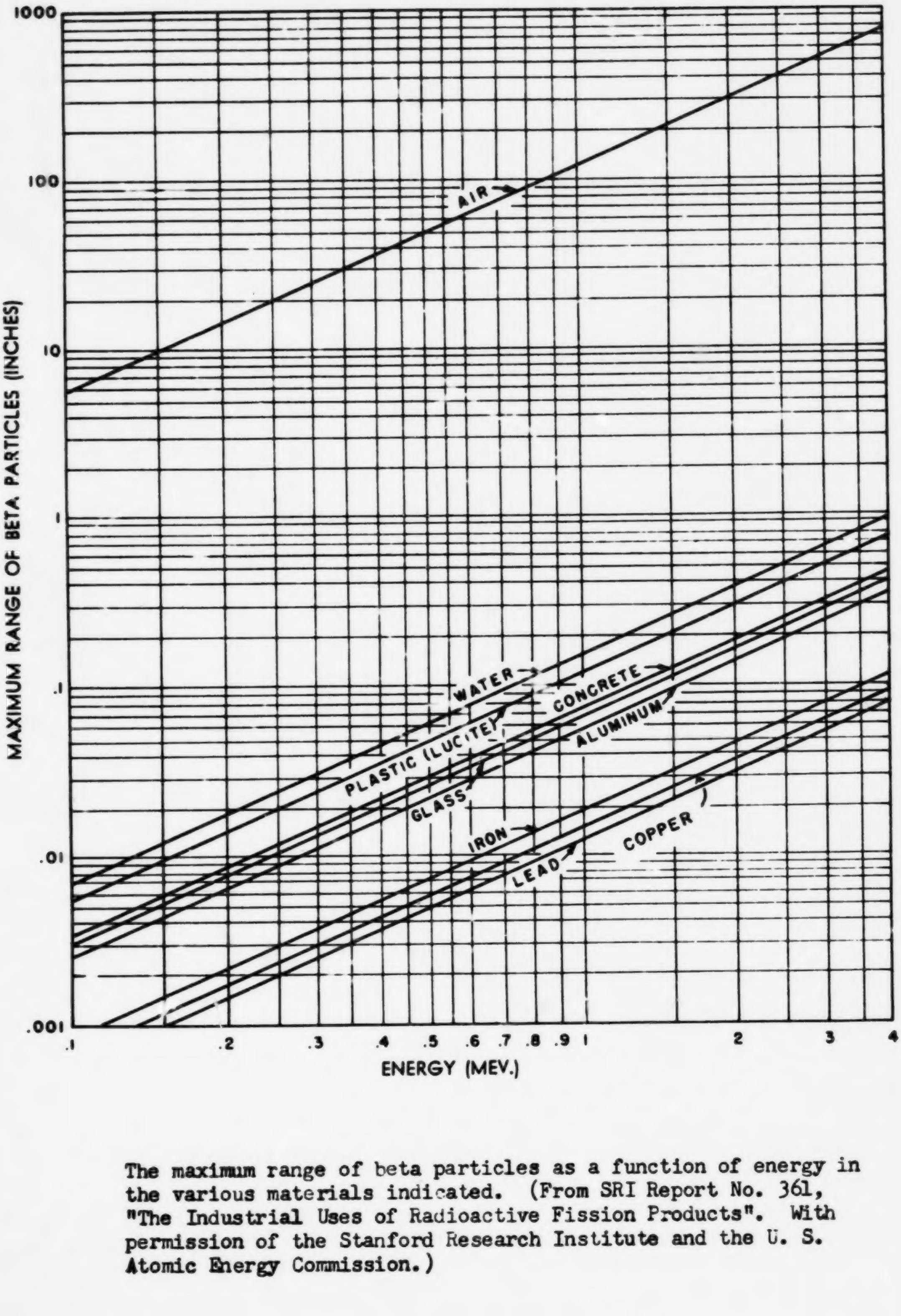
E_o (Mev)	$\mu_o x$						
	1	2	4	7	10	15	20
WATER							
.256	3.09	7.14	23.0	72.9	166	456	982
.5	2.52	5.14	14.3	38.8	77.6	178	334
1	2.13	3.71	7.68	16.2	27.1	50.4	82.2
2	1.83	2.77	4.88	8.46	12.4	19.5	27.7
3	1.69	2.42	3.91	6.23	8.63	12.8	17.0
4	1.58	2.17	3.34	5.13	6.94	9.97	12.9
6	1.46	1.91	2.76	3.99	5.18	7.09	8.85
8	1.38	1.74	2.40	3.34	4.25	5.66	6.95
10	1.33	1.63	2.19	2.97	3.72	4.90	5.98

DOSE BUILD-UP FACTOR FOR POINT ISOTROPIC SOURCE (Cont'd.)*

				$\mu_o x$			
E_o (Mev)	1	2	4	7	10	15	20
ALUMINUM							
.5	2.37	4.24	9.47	21.5	38.9	80.8	141
1	2.02	3.31	6.57	13.1	21.2	37.9	58.5
2	1.75	2.61	4.62	8.05	11.9	18.7	26.3
3	1.64	2.32	3.78	6.14	8.65	13.0	17.7
4	1.53	2.08	3.22	5.01	6.88	10.1	13.4
6	1.42	1.85	2.70	4.06	5.49	7.97	10.4
8	1.34	1.68	2.37	3.45	4.58	6.56	8.52
10	1.28	1.55	2.12	3.01	3.96	5.63	7.32
IRON							
.5	1.98	3.09	5.98	11.7	19.2	35.4	55.6
1	1.87	2.89	5.39	10.2	16.2	28.3	42.7
2	1.76	2.43	4.13	7.25	10.9	17.6	25.1
3	1.55	2.15	3.51	5.85	8.51	13.5	19.1
4	1.45	1.94	3.03	4.91	7.11	11.2	16.0
6	1.34	1.72	2.58	4.14	6.02	9.89	14.7
8	1.27	1.56	2.23	3.49	5.07	8.50	13.0
10	1.20	1.42	1.95	2.99	4.35	7.54	12.4
LEAD							
.5	1.24	1.42	1.69	2.00	2.27	2.65	2.73
1	1.37	1.69	2.26	3.02	3.74	4.81	5.86
2	1.39	1.76	2.51	3.66	4.84	6.87	9.00
3	1.34	1.68	2.43	3.75	5.30	8.44	12.3
4	1.27	1.56	2.25	3.61	5.44	9.80	16.3
5.1097	1.21	1.46	2.08	3.44	5.55	11.7	23.6
6	1.18	1.40	1.97	3.34	5.69	13.8	32.7
8	1.14	1.30	1.74	2.89	5.07	14.1	44.6
10	1.11	1.23	1.58	2.52	4.34	12.5	39.2

* Data from: H. Goldstein, J. E. Wilkins, Jr., S. Preiser, Interim Report of the NDA-NBS Calculations of Gamma Ray Penetration, NDA Memo 15C-20 (Nuclear Development Associates, White Plains, New York).

PENETRATION ABILITY OF BETA RADIATION



The maximum range of beta particles as a function of energy in the various materials indicated. (From SRI Report No. 361, "The Industrial Uses of Radioactive Fission Products". With permission of the Stanford Research Institute and the U. S. Atomic Energy Commission.)

MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE. (October 1951).

A. Common radioisotopes that are alpha emitters

Element	Organ (grams)	Microcuries in total body	Microcuries per milliliter of water	Microcuries per milliliter of air
Po^{210} (Sol.)	Spleen, 150	0.02	3×10^{-5}	2×10^{-10}
Po^{210} (Insol.)	Lungs, 10^3	7×10^{-3}	---	7×10^{-11}
Rn^{222} + dr (e)	Body, 7×10^4	---	2×10^{-6}	---
	Lungs, 10^3	---	---	10^{-8}
Ra^{226} + $\frac{1}{2}$dr (e)	Bone, 7×10^3	0.1	4×10^{-8}	8×10^{-12}
U-natural (Sol.)	Kidneys, 300	0.2 (b)	7×10^{-5} (b)	1.7×10^{-11} (b)
U-natural (Insol.)	Lungs, 10^3	0.009	---	1.7×10^{-11} (b)
U^{233} (Sol.)	Bone, 7×10^3	0.04	1.5×10^{-4}	1×10^{-10}
U^{233} (Insol.)	Lungs, 10^3	0.008	---	1.6×10^{-11}
Pu^{239} (Sol.)	Bone, 7×10^3	0.04	1.5×10^{-6}	2×10^{-12}
Pu^{239} (Insol.)	Lungs, 10^3	0.008	---	2×10^{-12}

a. Tables A, B, and C from National Bureau of Standards Handbook 52.

b. Based on chemical toxicity. The microcurie and microcurie-per-milliliter values are given for the natural mixture of U^{238}, U^{235}, and U^{234} with all the other radioisotopes removed.

c. Percentages of stable element by weight comprising total body. The other principal body elements, oxygen (65%), nitrogen (3%), and magnesium (4×10^{-3}%), are omitted because all their radioactive isotopes have very short half-lives.

d. Obtained by a comparison of recommended values for Sr^{90} with the calculated values in the two cases.

e. Values of microcuries and microcuries-per-milliliter are given for the parent element in equilibrium with its daughter element(s).

MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE. (October 1951). - Continued

B. Beta- and gamma-emitting radioisotopes that are of interest because they are common body elements.

Element and percentage in body (c)	Organ (grams)	Microcuries in total body	Microcuries per milliliter of water	Microcuries per milliliter of air
H^3 (HTO or $H^3{}_2O$), 10%	Total Body, 7×10^4	10^4	0.2	2×10^{-5}
C^{14} (CO_2), 18%	Fat, 10^4	250	3×10^{-3}	10^{-6}
	Bone, 7×10^3	1,500	4×10^{-3}	5×10^{-7}
Na^{24}, 0.15%	Total Body, 7×10^4	15	8×10^{-3}	2×10^{-6}
P^{32}, 1.0%	Bone, 7×10^3	10	2×10^{-4}	1×10^{-7}
S^{35}, 0.25%	Skin, 2×10^3	100	5×10^{-3}	10^{-6}
Cl^{36}, 0.15%	Total Body, 7×10^4	200	2×10^{-3}	4×10^{-7}
K^{42}, 0.35%	Muscle, 3×10^4	20	1×10^{-2}	2×10^{-6}
Ca^{45}, 1.5%	Bone, 7×10^3	65	5×10^{-4}	3×10^{-8}
Mn^{56}, 3×10^{-4}%	Kidneys, 300	2	0.15	3×10^{-6}
	Liver, 1.7×10^3	7.5	0.3	4×10^{-6}
Fe^{55}	Blood, 5×10^3	1×10^3	4×10^{-3}	6×10^{-7}
Fe^{59} – 0.004%	Blood, 5×10^3	11	1×10^{-4}	1.5×10^{-8}
Cu^{64}, 2×10^{-4}%	Liver, 1.7×10^3	1.5×10^2	8×10^{-2}	6×10^{-6}
Zn^{65}, 0.003%	Bone, 7×10^3	430	6×10^{-2}	2×10^{-6}
I^{131}, 4×10^{-5}%	Thyroid, 20	0.3	3×10^{-5}	3×10^{-9}

MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE. (October 1951). - Continued

C. Other radioisotopes of current interest.

Element	Organ (grams)	Microcuries in total body	Microcuries per milliliter of water	Microcuries per milliliter of air
Be^{7}	Bone, 7×10^{3}	670	1	4×10^{-6}
F^{18}	Bone, 7×10^{3}	24	0.9	10^{-4}
A^{41}	Total Body, 7×10^{4}	30	5×10^{-4}	5×10^{-7}
Sc^{46}	Spleen, 150	6	0.4	7×10^{-8}
V^{48}	Bone, 7×10^{3}	20	0.5	10^{-6}
Cr^{51}	Kidneys, 300	390	0.5	8×10^{-6}
Co^{60}	Liver, 1.7×10^{3}	3	2×10^{-2}	10^{-6}
Ni^{59}	Liver, 1.7×10^{3}	39	0.25	2×10^{-5}
Ga^{72}	Bone, 7×10^{3}	8	9	3×10^{-6}
Ge^{71}	Kidneys, 300	67	9	4×10^{-5}
As^{76}	Kidneys, 300	10	0.2	2×10^{-6}
Rb^{86}	Muscle, 3×10^{4}	60	3×10^{-3}	4×10^{-7}
Sr^{89}	Bone, 7×10^{3}	2	7×10^{-5} (d)	2×10^{-8} (d)
$Sr^{90} + Y^{90}$ (e)	Bone, 7×10^{3}	1	8×10^{-7}	2×10^{-10}
Y^{91}	Bone, 7×10^{3}	15	0.2	4×10^{-8}
Nb^{95}	Bone, 7×10^{3}	90	4×10^{-3}	4×10^{-7}
Mo^{99}	Bone, 7×10^{3}	50	14	2×10^{-3}
Tc^{96}	Kidneys, 300	5	3×10^{-2}	3×10^{-6}
$Ru^{106} + Rh^{106}$ (e)	Kidneys, 300	4	0.1	3×10^{-8}
Rh^{105}	Kidneys, 300	9	1.5×10^{-2}	10^{-6}
$Pd^{103} + Rh^{103}$ (e)	Kidneys, 300	6	1×10^{-2}	7×10^{-7}
Ag^{105}	Liver, 1.7×10^{3}	18	2	10^{-5}
Ag^{111}	Liver, 1.7×10^{3}	36	4	3×10^{-5}
$Cd^{109} + Ag^{109m}$ (e)	Liver, 1.7×10^{3}	40	7×10^{-2}	7×10^{-8}
Sn^{113}	Bone, 7×10^{3}	80	0.2	6×10^{-7}
Te^{127}	Kidneys, 300	4	3×10^{-2}	10^{-7}
Te^{129}	Kidneys, 300	1.3	10^{-2}	4×10^{-8}

MAXIMUM PERMISSIBLE AMOUNT OF RADIOISOTOPE IN TOTAL BODY AND MAXIMUM PERMISSIBLE CONCENTRATION IN AIR AND WATER FOR CONTINUOUS EXPOSURE. (October 1951). - Continued

C. Other radioisotopes of current interest - Continued

Element	Organ (grams)	Microcuries in total body	Microcuries per milliliter of water	Microcuries per milliliter of air
Xe^{133}	Total Body, 7×10^4	300	4×10^{-3}	4×10^{-6}
Xe^{135}	Total Body, 7×10^4	100	1×10^{-3}	2×10^{-6}
$Cs^{137} + Ba^{137m}$ (e)	Muscle, 3×10^4	90	1.5×10^{-3}	2×10^{-7}
$Ba^{140} + La^{140}$ (e)	Bone, 7×10^3	5	2×10^{-3}	6×10^{-8}
La^{140}	Bone, 7×10^3	24	1	10^{-6}
$Ce^{144} + Pr^{144}$ (e)	Bone, 7×10^3	5	4×10^{-2}	7×10^{-9}
Pr^{143}	Bone, 7×10^3	29	0.4	7.5×10^{-7}
Pm^{147}	Bone, 7×10^3	120	1	2×10^{-7}
Sm^{151}	Bone, 7×10^3	420	0.2	10^{-8}
Eu^{154}	Bone, 7×10^3	22	3×10^{-2}	6×10^{-9}
Ho^{166}	Bone, 7×10^3	17	23	3×10^{-6}
Tm^{170}	Bone, 7×10^3	19	0.25×10^{-1}	5×10^{-8}
Lu^{177}	Bone, 7×10^3	72	24	5×10^{-6}
Re^{183}	Thyroid, 20 Skin, 2×10^3	35 600	8×10^{-2} 0.2	8×10^{-6} 2×10^{-5}
Ir^{190}	Kidneys, 300	21	10^{-2}	7×10^{-7}
Ir^{192}	Kidneys, 300	3.4	9×10^{-4}	5×10^{-8}
Au^{198}	Kidneys, 300	10	3×10^{-3}	1×10^{-7}
Au^{199}	Kidneys, 300	28	7×10^{-3}	2.5×10^{-7}
Pb^{203}	Bone, 7×10^3	57	0.1	6.5×10^{-6}
At^{211}	Thyroid, 20	6×10^{-4}	2×10^{-6}	3×10^{-10}
Th^{234}	Bone, 7×10^3	120	3	6×10^{-7}
Am^{241}	Bone, 7×10^3	0.056	10^{-4}	3×10^{-11}
Cm^{242}	Bone, 7×10^3	0.05	9×10^{-4}	2×10^{-10}

MAXIMUM PERMISSIBLE TISSUE DOSE LIMITS IN "REPS" PER WEEK - 1950 CHALK RIVER CONFERENCE

Type of Radiation	At Any Point Within the Body	Relative Biological Effectiveness	In Basal Layer of Epidermis Exposure of Entire Body	In Basal Layer of Epidermis Exposure of Hands Only
X and γ rays	0.3	1	0.5	1.5
Beta rays	0.3	1	0.5	1.5
Protons	0.03	10	0.05	0.15
Alpha Rays	0.015	20	0.025	0.075
Fast Neutrons	0.03	10	0.05	0.15
Thermal Neutrons	0.06	5	0.1	0.3

SUGGESTED EMERGENCY LEVELS FOR FOOD AND WATER IMMEDIATELY FOLLOWING A NUCLEAR EXPLOSION

CONSUMPTION PERIOD	BETA ACTIVITY LEVELS		ALPHA ACTIVITY LEVELS	
	MICROCURIES PER CC	DISINTEGRATIONS PER MIN PER CC	MICROCURIES PER CC	DISINTEGRATIONS PER MIN PER CC
PREFERABLE RISK				
10 days	3.5×10^{-3}	7.7×10^{3}	2×10^{-4}	440
30 days	1.1×10^{-3}	2.6×10^{3}	6.7×10^{-5}	145
ACCEPTABLE RISK				
10 days	9×10^{-2}	2×10^{5}	5×10^{-3}	1.1×10^{4}
30 days	3×10^{-2}	7×10^{4}	1.7×10^{-3}	3.7×10^{3}

It is emphasized that these are not peacetime permissible levels of radioactivity for either short or long term consumption. Responsible officials can utilize these values during periods of emergency with the conviction that water with radioactivity falling below these limits can be used with no real hazard.

The beta-gamma values do not apply for periods later than one month after a nuclear explosion, since the longer lived radioactivity remaining carries an increasing hazard for human consumption.

SIGNIFICANT FISSION PRODUCTS

Isotope	Symbol	Contribution to total activity, percent					Half-Life
		1 day	10 days	30 days	90 days	1 year	
Strontium	Sr^{89}	---	2.8	6.7	10.5	2.7	53d
Strontium	Sr^{91}	6.7	---	---	---	---	9.7h
Strontium	Sr^{90}	---	---	---	1.8	19.9	19.9y
Yttrium	Y^{90}						61h
Yttrium	Y^{91}	2.9	*3.4	*7.6	*12.5	*3.9	61d
Yttrium	Y^{92}	4.2	---	---	---	---	3.6h
Yttrium	Y^{93}	7.6	---	---	---	---	10h
Zirconium	Zr^{95}	---	3.7	8.2	14.7	7.3	65d
Zirconium	Zr^{97}	9.0	---	---	---	---	17.0h
Niobium	Nb^{95}	---	---	*4.1	*18.2	*15	35d
Niobium	Nb^{97}	9.0	---	---	---	---	72.1m
Molybdenum	Mo^{99}	4.6	6.8	---	---	---	67.0h
Ruthenium	Ru^{103}	---	2.65	5.7	7.2	---	39.8d
Ruthenium	Ru^{106}	---	---	---	---	2.4	1.0y
Rhodium	Rh^{106}						30s
Rhodium	Rh^{103}	---	1.55	5.5	7.0	---	57m
Rhodium	Rh^{105}	1.35	---	---	---	---	36.5h
Tellurium	Te^{132}	2.6	5.1	---	---	---	77.7h
Iodine	I^{131}	---	6.8	3.7	---	---	8.14d
Iodine	I^{132}	2.7	5.3	---	---	---	2.4h
Iodine	I^{133}	7.3	---	---	---	---	20.5h
Iodine	I^{135}	4.7	---	---	---	---	6.68h
Xenon	Xe^{133}	1.23	11.4	2.6	---	---	5.27d
Xenon	Xe^{135}	*12.5	---	---	---	---	9.13h

SIGNIFICANT FISSION PRODUCTS (Continued)

Isotope	Symbol	Contribution to total activity, percent					Half-Life
		1 day	10 days	30 days	90 days	1 year	
Cesium	Cs^{137}	---	---	---	---	1.5	33y
Barium	Ba^{137m}						2.6m
Barium	Ba^{140}	1.25	10.6	10.8	1.6	---	12.8d
Lanthanum	La^{140}	---	12.0	12.5	2.4	---	40h
Lanthanum	La^{141}	1.4	---	---	---	---	3.7h
Cerium	Ce^{141}	---	6.3	11.2	8.5	---	33.1d
Cerium	Ce^{143}	6.8	---	---	---	---	33h
Cerium	Ce^{144}	---	---	2.0	6.0	26.5	282d
Praseodymium	Pr^{144}						17.5m
Praseodymium	Pr^{143}	---	10.0	11.2	1.9	---	13.7d
Neodymium	Nd^{147}	---	4.8	4.1	---	---	11.3d
Promethium	Pm^{147}	---	---	---	---	5.7	2.6y
Promethium	Pm^{149}	1.45	---	---	---	---	54h

* Contribution from both metastable and ground state.

The data in the above table were taken from an article "Fission Product Decay Rates" by Hunter and Ballou as published in Nucleonics, pages C-2 - 7, Vol. 9, No. 5, November, 1951.

The fission products which contribute one percent or more of the total activity at any given time are the only ones included herein and a blank entry such as --- for any particular time for the nuclides listed is used to indicate the contribution was less than one percent.

DECONTAMINATION METHODS

Surface	Method	Advantages	Disadvantages
Paint	Water	Most practical method of gross decontamination.	Protection needed from contaminated spray. Runoff must be controlled.
	Detergents	Most commonly available reagent.	Mild action.
	Complexing agents: Oxalates, carbonates, citrates.	Holds contamination in solution.	Requires application from 5 to 30 minutes for effectiveness. Has little penetrating power; hence of small value on weathered surfaces.
	Organic solvents	Quick dissolving action makes solvents useful on vertical and overhead surfaces.	Toxic and flammable. Requires good ventilation and fire precautions.
	Caustics	Minimum contact with contaminated surface. Contamination reduced almost 100 percent.	Applicable only on horizontal surfaces. Personnel hazard. Not to be used on aluminum or magnesium.
	Abrasion (wet)	Complete removal of surface and contamination. Feasible for large-scale operations.	Method too harsh for many surfaces.
Glassware	Detergent	Readily available	Efficiency depends on nature of contaminant.

DECONTAMINATION METHODS (Cont'd)

Surface	Method	Advantages	Disadvantages
Glassware (Cont'd)	Reagents (mineral acids, trisodium phosphate, etc.)	Nature of contaminant determines choice of reagent.	Single reagent not suitable for all contaminant. Repeated application of small quantities more effective than single application of large volume.
Metal	Water	Most practical method of gross decontamination.	Same as for painted surfaces.
	Detergents	Removal of oil or grease films.	Same as for painted surfaces.
	Organic solvents	Stripping of grease.	Same as for painted surfaces.
	Complexing agents: Oxalates, carbonates, citrates.	Holds contamination in solution.	Difficult to keep in place on any but horizontal surfaces. Limited value on weathered porous surfaces.
	Inorganic acids	Fast, complete decontamination.	Good ventilation required; acid fumes toxic to personnel. Possibility of excessive corrosion.
	Acid mixtures	Action of weak acid. Reduces contamination of unweathered surfaces.	Same as for inorganic acids.

DECONTAMINATION METHODS (Cont'd)

Surface	Method	Advantages	Disadvantages
Metal (Cont'd)	Abrasion (wet)	Same as for paint.	Control of powdered contaminant necessary. Method too harsh for many surfaces.
Concrete and Brick	Abrasion (vacuum blasting)	Direct and complete removal of contaminated dust.	Contamination of equipment.
	Vacuum cleaning	Same as for vacuum blasting on concrete. Less effective than vacuum blasting.	Same as for vacuum blasting on concrete.
Wood	Planing	Complete removal. Minimum dust hazard.	May impair utility.

Best decontamination can usually be accomplished by removal of a strippable coating which has been applied previous to contamination.

PHOTOGRAPHIC EMULSIONS USEFUL FOR RADIATION MEASUREMENT IN PERSONNEL MONITORING

EMULSION	APPROXIMATE RANGE*(roentgens)
Ansco Films	
Superay "A" X-Ray	0.2 to 3.0
Non Screen X-Ray	0.1 to 2.0
Dupont Films	
Dupont 502	0.05 to 10.0
Dupont 508	0.015 to 5.0
Dupont 510	0.5 to 20.0
Dupont 605	10.0 to 250
Defender Adlux	5.0 to 2000
Eastman Films	
Kodak Industrial Type K	0.01 to 2.0
Kodak Industrial Type A	0.1 to 5.0
Cine Positive 5302	10.0 to 200
548-O Double Coat	200 to 5,000
548-O Single Coat	5,000 to 20,000

* The listed ranges represent sensitivities to X- radiation of an effective energy of approximately 600 kev, for film developed in Eastman X-ray developer for five minutes at 20°C. Film sensitivity varies greatly with the effective energy of radiation up to 250 kev reaching a peak at approximately 40 kev effective. The upper limit of the range is based on a maximum useful optical density of 3.0. The useful range will depend also on the developer and processing procedures.

Dupont 502 and 510 films are combined in the Dupont 552 packet; and Dupont 508 and Defender Adlux in the Dupont 558 packet.

BETA RAY SURFACE DOSE RATE FOR URANIUM AND SOME URANIUM COMPOUNDS

with filter of 7± 0.4 mg/cm^2 polystyrene

Source	Dose Rate mrep/hr.	Source	Dose Rate mrep/hr.
U SLUG	239	UO_3 (Orange oxide)	208
UO_2 (Brown oxide)	212	U_3O_8 (Black oxide)	207
UF_4 (Green salt)	183	UO_2F_2 (Cliptite or uranyl fluoride)	181
$UO_2(NO_3)_2$ 6 H_2O (Yellow uranyl nitrate hexahydrate)	114	$Na_2U_2O_7$ (Soda salt or Sodium Diuranate)	171

Dose rate measured with an extrapolation chamber. Data taken from AECD-2753.

SELECTED THERMAL NEUTRON ACTIVATION REACTIONS USEFUL IN NEUTRON DETECTION AND ACTIVATION EXPERIMENTS

Element	Atomic Activation Cross Section (barns)	Half-life and Emission	Radioactive Product
Dy	2860*	1.25m (IT)	Dy^{165}
	2620*	2.3h (β^-,γ)	Dy^{165}
Eu	1400*	9.2h (β^-, EC, γ)	Eu^{152}
In	145 ± 15	54m (β^-,γ)	In^{116}
	52 ± 6	13s (β^-)	In^{116}
	56 ± 12	49d (IT, no EC)	In$^{\underline{114}}$
Rh	140 ± 30	44s (β^-,γ)	Rh^{104}
	12 ± 2	4.4m (IT)	Rh^{104}
Ag	110 ± 20	24.2s (β^-,γ)	Ag^{110}
	44 ± 9	2.3m (β^-, EC, γ)	Ag^{108}
	2.8 ± 0.5	270d (β^-, IT, γ)	Ag^{110}
Au	96 ± 10	2.69d (β^-,γ)	Au^{198}
Ho	60 ± 12	27.3h (β^-,γ)	Ho^{166}
W	40 ± 10	24.1h (β^-,γ)	W^{187}
Co	20 ± 3	5.27h (β^-,γ)	Co^{60}
	14 ± 3	10.1m (IT, β^-,γ)	Co^{60}
Mn	12 ± 2	2.57h (β^-,γ)	Mn^{56}
I	6.3 ± 1.3	24.99m (β^-, EC, γ)	I^{128}
V	4.5 ± 0.9	3.76m (β^-,γ)	V^{52}
Cu	3.9 ± 0.8	12.8h (β^-, β^+, EC, γ)	Cu^{64}
	1.8 ± 0.4	5.1m (β^-,γ)	Cu^{66}
Fe	0.7 ± 0.3	2.94y (EC)	Fe^{55}
	0.7 ± 0.2	45.1d (β^-,γ)	Fe^{59}
Na	0.6 ± 0.2	15.06h (β^-,γ)	Na^{24}
Cd	1.1 ± 0.3	2.21d (β^-,γ)	Cd^{115}
	0.2 ± 0.1	48.6m (IT)	Cd$^{\underline{111}}$
	1.4 ± 0.3	3.0h (IT)	Cd^{117}
	0.02 ± 0.01	5.1y (β^-)	Cd$^{\underline{113}}$
	0.14 ± 0.03	43d (β^-,γ)	Cd$^{\underline{115}}$
	1.0 ± 0.5	6.7h (EC, γ)	Cd^{107}
P	0.23 ± 0.05	14.3d (β^-)	P^{32}

* Cross section values taken from NBS Circular 499. All other cross section data taken from AECU-2040. Half-life values taken from the table of isotopes appended to this handbook. The isotopic activation cross sections reported by an experimenter depend upon the values of half-life used in his calculations. Since most of the activation measurements are good only to about 20 percent, corrections have not been made for the differences in half-life between those listed, and those used in the calculation of the cross sections.

Table arranged in order of decreasing cross section. Underscored mass numbers indicate metastable nuclear isomers. Neutron velocity is 2200 m/sec.

SELECTED (n,p) REACTIONS USEFUL IN THRESHOLD NEUTRON DETECTION

Original Nucleus	Energetic Threshold (Mev)	Activation Cross Section (mb)	Maximum Error (%)	Convenient Material	Radioactive Isotope	Half-Life & Emission	Other Activities
Mg^{24}	2.1	39	10	Mg metal	Na^{24}	14.8h(β,γ)	10.2m(n,γ)
Al^{27}	2.1	25	10	Al metal	Mg^{27}	10.2m(β,γ)	2.4m(n,γ)
Si^{28}	3.9	45	12	H_2SiO_3	Al^{28}	2.4m(β,γ)	170m(n,γ); 6.7m(n,p)
Si^{29}	1.8	36	15	H_2SiO_3	Al^{29}	6.7m(β)	170m(n,γ); 2.4m(n,γ)
P^{31}	1.1	120	10	$(NH_4)H_2PO_4$	Si^{31}	170m(β)	2.5m(n,2n)
S^{32}	1.0	285	5	Flower of Sulfur	P^{32}	14.3d(β)	None
Ti^{49}	1.1	6.5	10	Ti metal powder	Sc^{49}	57m(β)	3.0h(n,2n); 44h(n,p)
Cr^{52}	2.8	15	10	Cr_2O_3	V^{52}	3.9m(β,γ)	42.0m(n,2n)
Fe^{56}	2.9	18.5	8	Fe metal	Mn^{56}	2.59h(β,γ)	None
Cu^{65}	2.3	3.2	40	Cu metal	Ni^{65}	2.6h(β,γ)	10.1m(n,2n); 5m(n,γ); 12.8h(n,γ)
Zn^{66}	3.5	11.0	10	Zn metal	Cu^{66}	5m(β,γ)	57m(n,γ); 13.8h(n,γ); 38m(n,2n)
Ag^{109}	0.4	2.0	30	Ag metal	Pd^{109}	13h(β)	2.3m(n,γ); 24.5m(n,2n)

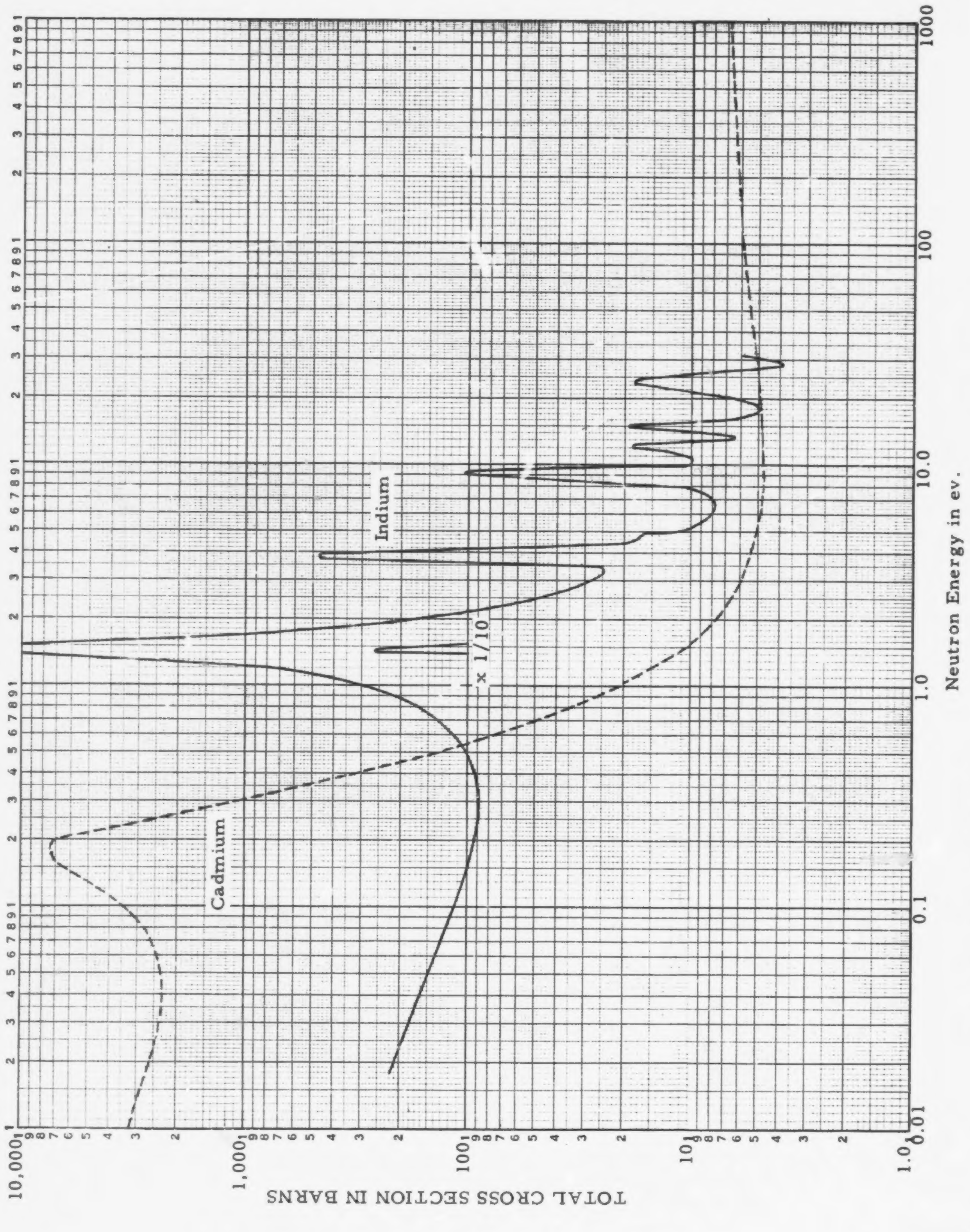
Data from: Bernard L. Cohen, "(n,2n) and (n,p) Cross Sections", The Physical Review, Vol. 81, No. 2, pp. 184-188, January 15, 1951.

SELECTED (n,2n) REACTIONS USEFUL IN NEUTRON DETECTION

Original Nucleus	Energetic Threshold (Mev)	Activation Cross Section σ (mb)	Error in σ (±)	Convenient Material	Radioactive Isotope	Half-Life & Emission	Other Activities
N^{14}	10.6	0.255	0.02	Urea NH_4NO_3	N^{13}	10.1m(β^+)	None
F^{19}	10.4	2.27	0.23	LiF	F^{18}	112m(β^+)	None
P^{31}	12.3	14.4	1.5	Ca_3P_2	P^{30}	2.55m(β^+)	170m(n,p); 2.5h Ca(n,γ)
Cr^{50}	13.4	1.07	0.15	Cr_2O_3	Cr^{49}	42m(β^+,γ)	3.9(n,p)
Ni^{58}	11.7	2.9	0.7	Ni metal	Ni^{57}	36h(β^+,γ)	2.6h(n,γ) 72d(n,p)
As^{75}	10.3	50	10	As_2O_3	As^{74}	16d(β,β^+,γ)	26.8h(n,γ)
Ag^{107}	9.6	42	3	Ag metal	Ag^{106}	24.5m(β^+)	2.3m(n,γ); 13h(n,p)
Sb^{121}	9.25	40	4	Sb_2O_3	Sb^{120}	16m(β^+)	2.8d(n,γ)
I^{127}	9.45	31	3	NH_4I	I^{126}	13.0d(β)	25m(n,γ)
Pr^{141}	9.4	39	4	Pr_6O_{11}	Pr^{140}	3.5m(β^+)	Long

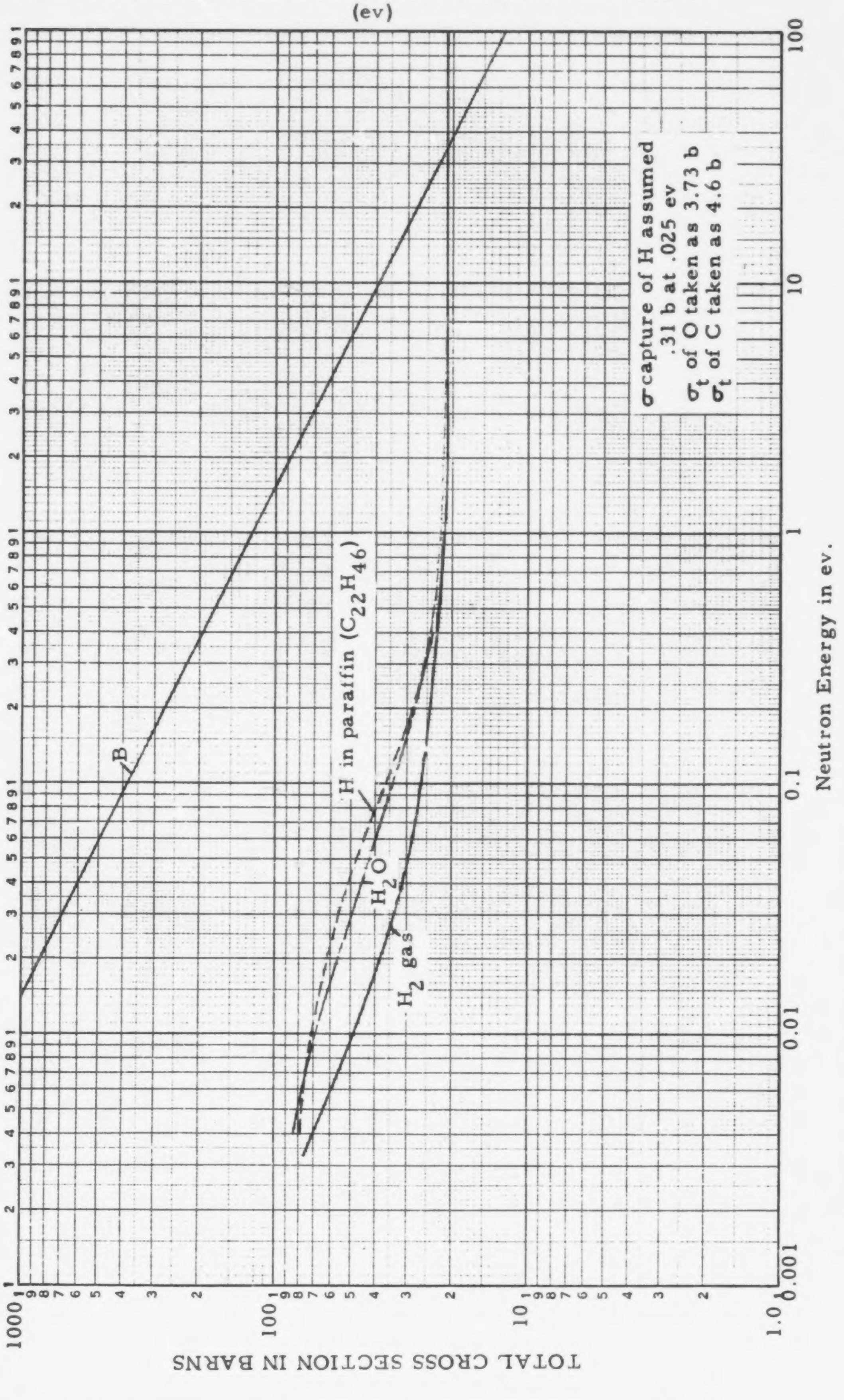
Data from: Bernard L. Cohen, "(n,2n) and (n,p) Cross Sections", The Physical Review, Vol. 81, No. 2, pp. 184-188, January 15, 1951.

TOTAL NEUTRON CROSS SECTIONS FOR INDIUM AND CADMIUM



Data taken from AECU-2040.

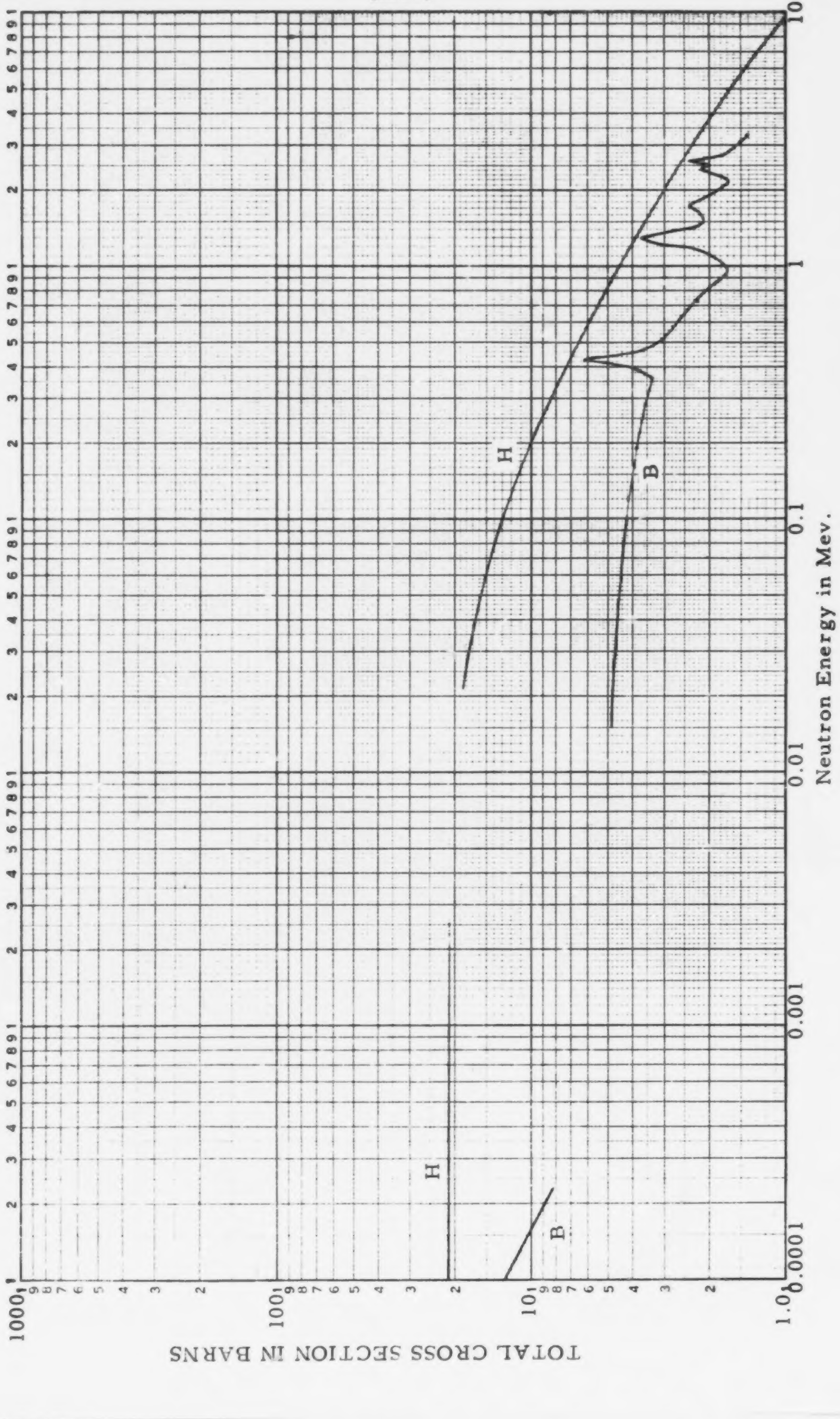
NEUTRON CROSS SECTIONS FOR HYDROGEN AND BORON



Cross sections for boron taken from AECU-2040; for H in paraffin from Havens and Rainwater, Rev. Mod. Phy. 19, 4 (1947); for H_2 and H_2O from Edward Melkonian, Phys. Rev. 76, 1750 (1949).

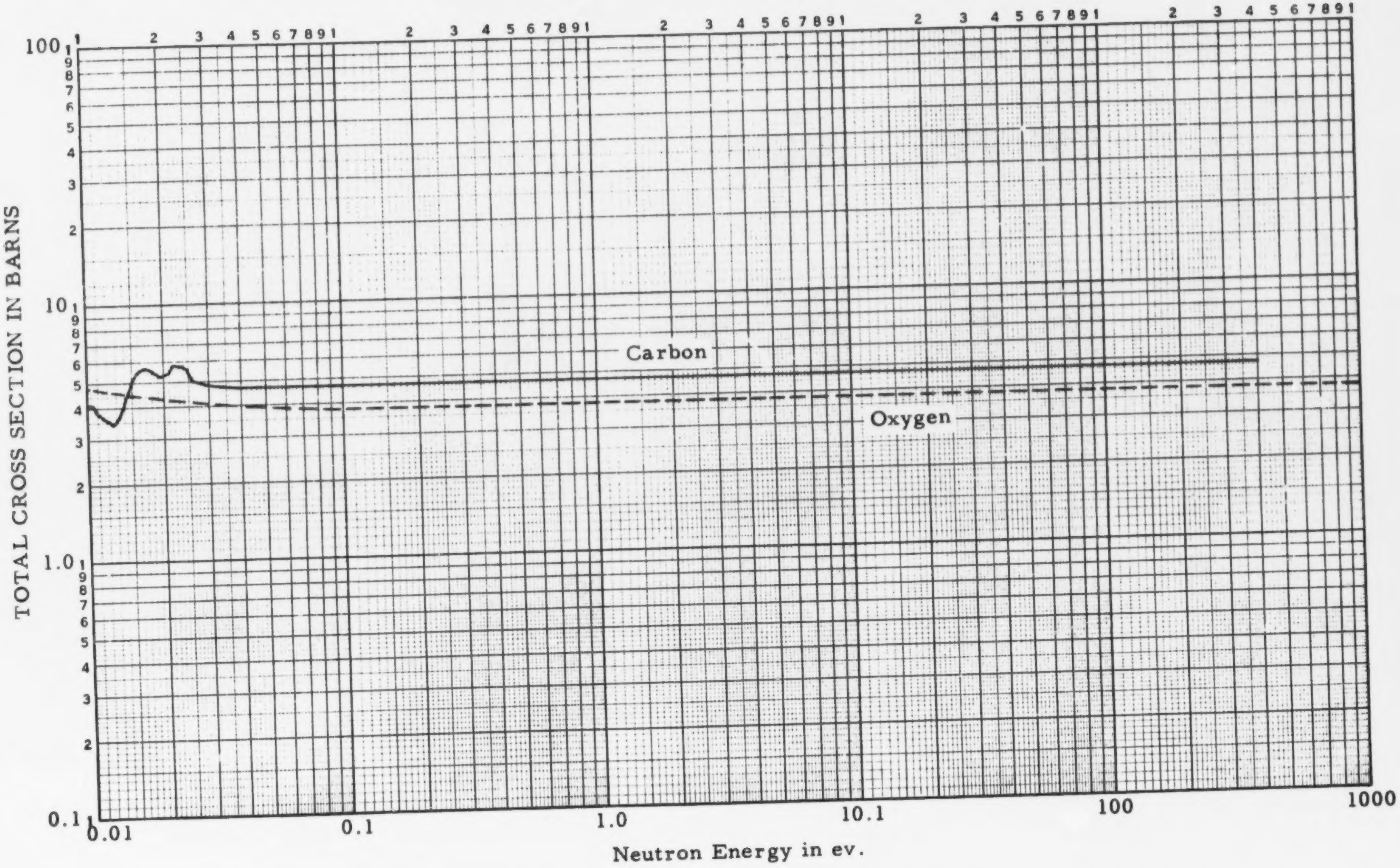
NEUTRON CROSS SECTIONS FOR HYDROGEN AND BORON

(Mev)



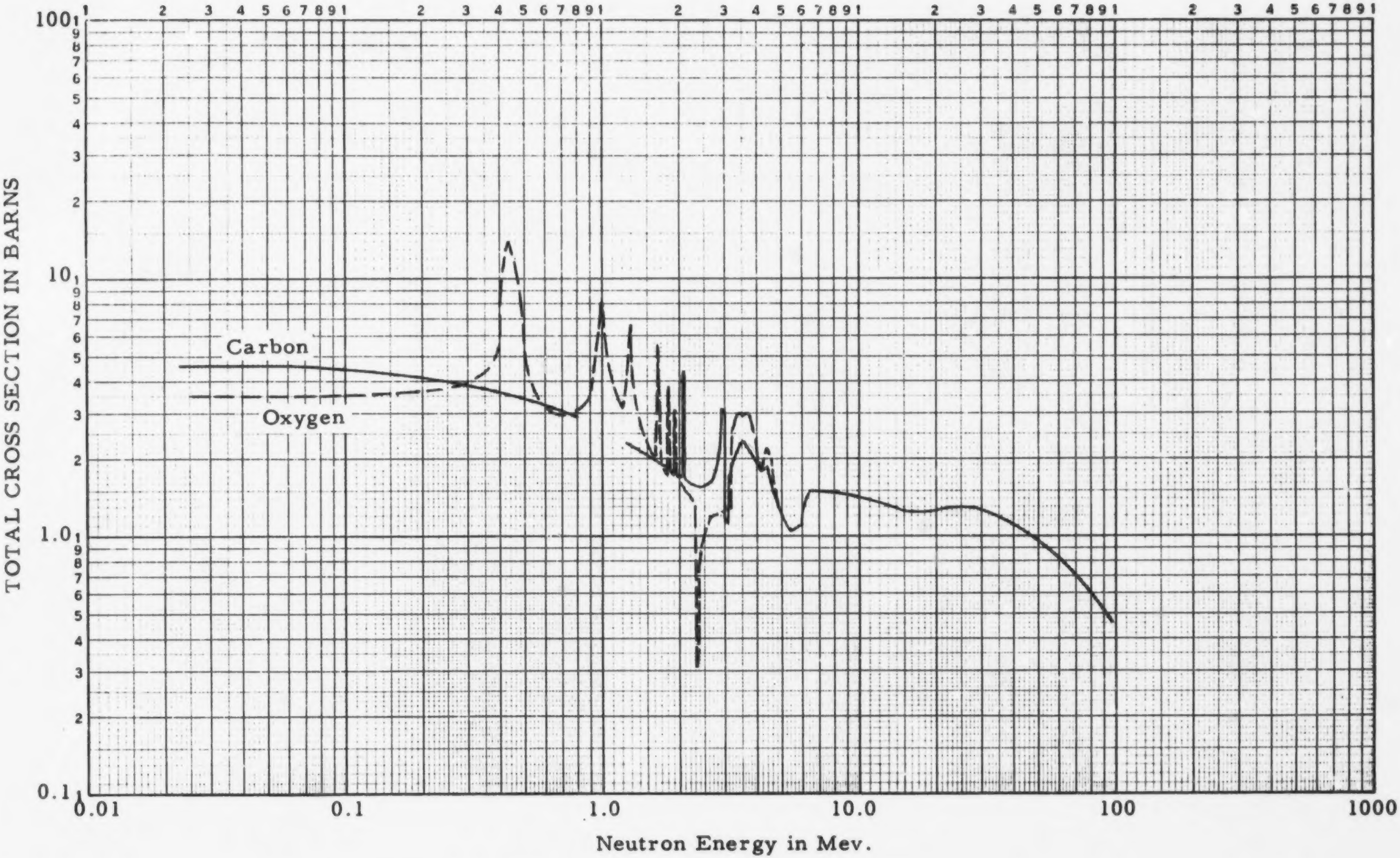
Data taken from AECU-2040.

TOTAL NEUTRON CROSS SECTIONS FOR CARBON AND OXYGEN

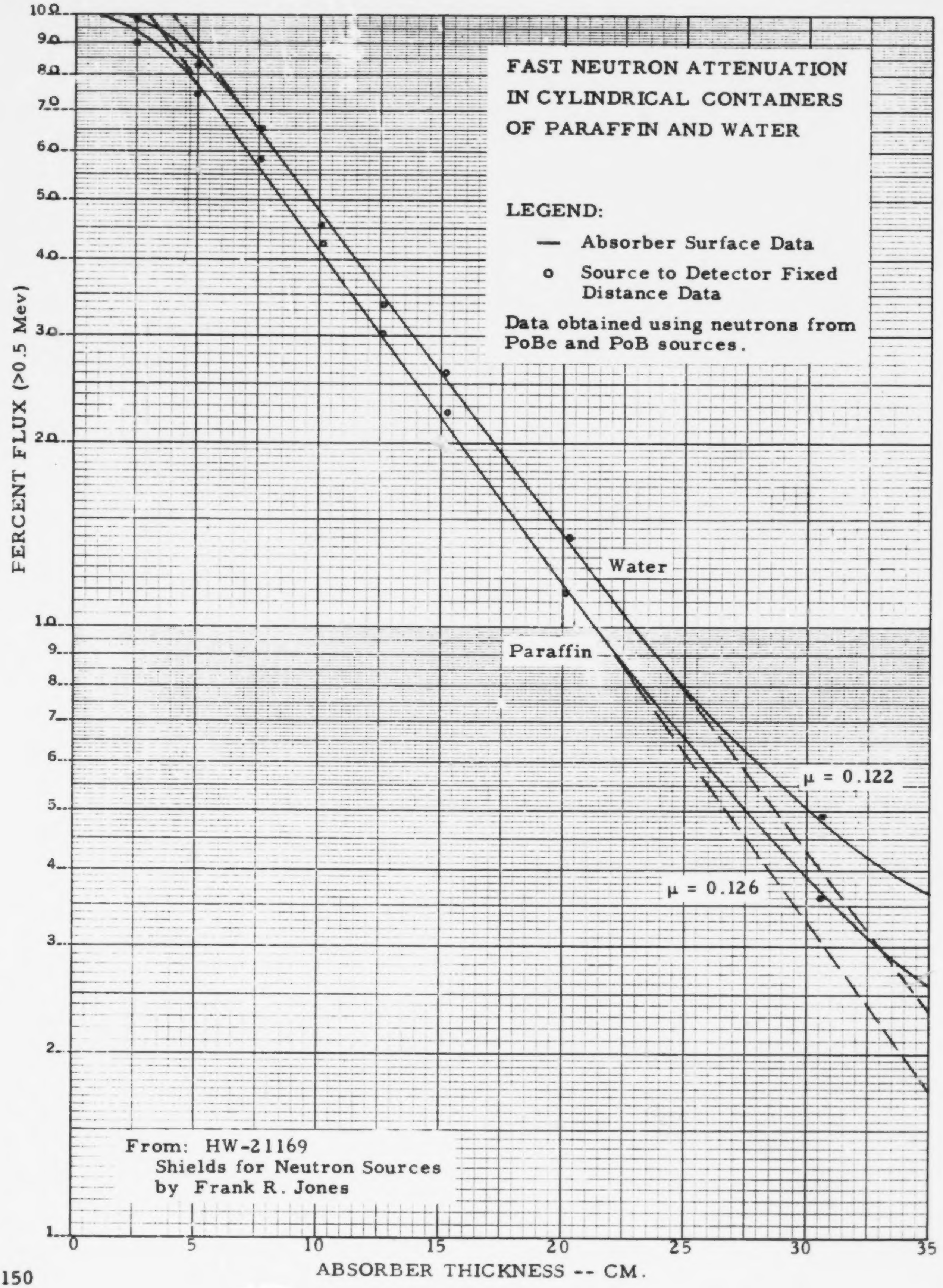


Data taken from AECU-2040.

TOTAL NEUTRON CROSS SECTIONS FOR CARBON AND OXYGEN



Data taken from AECU-2040.



FAST NEUTRON ATTENUATION IN CYLINDRICAL CONTAINERS OF PARAFFIN AND WATER

LEGEND:

— Absorber Surface Data

o Source to Detector Fixed Distance Data

Data obtained using neutrons from PoBe and PoB sources.

From: HW-21169
Shields for Neutron Sources
by Frank R. Jones

X-RAY BARRIER COMPUTATION

Data on pages 151 thru 157 have been extracted from National Bureau of Standards Handbook 50, X-ray Protection Design. This handbook should be consulted for a detailed presentation of x-ray protection considerations.

The graphs on pages 153 thru 156 are experimental radiation attenuation curves for lead and concrete for the useful beam, under broad-beam conditions. The ordinates of the curves give the dosage rate of the useful beam beyond the barrier in roentgens per minute at a point 1 m from the target for a target current of 1 ma. The abscissas are thickness of the specified barrier material that reduces the dosage rate of the 1 ma beam, as shown by the ordinates. Barrier requirements at other distances and radiation outputs are computed on the basis of the dosage rate at 1 m. If the tube current is increased above 1 ma, the barrier requirements will be increased; if the distance between the tube and the point to be protected is increased, the barrier requirements will be decreased.

The figures, therefore, indicate directly the barrier thickness required to reduce the dosage rate to the permissible value of 10^{-4} r/min. (assuming continuous exposure during a 48 hour work-week) for 1 ma and at 1 m from the target. By simple calculations the graphs may be used also for other conditions. In general, the required lead equivalent of the barrier may be obtained from the appropriate curve by using as the ordinate the dosage rate Y_u, where

$$Y_u = 9.7 \frac{C^2}{i} \times 10^{-6}$$

and C is the distance in feet between the target and the nearest position to be occupied by personnel during the exposure, and i is the target current in milliamperes. (In some cases, where the working time is less than a full work week, the value used for i may be that target current which will produce the same amount of radiation when the tube is operated 48-hours, as the target current and work week in question.)

As absorption curves are not available for scattered radiation, it is customary to use the same absorption curve for the scattered radiation as for the useful beam when the x-ray potential is less than 500-kv, and the 500-kv curve for all higher x-ray tube potentials. As the dosage rate must be reduced to 10^{-4} r/min. at positions to be occupied by personnel, the radiation in roentgens per milliampere minute at 1 m from the target required to give such levels of scattered radiation is given by

$$S_{500} = \frac{9\,d^2\,D^2}{i} \times 10^{-4}$$

for x-ray tube potentials of 500-kv or below. Here D is the distance in feet between the target and scatterer, and d is the distance between the scatterer and the position in occupied space. For 1000-kv potentials, since the output is roughly 10 times as great as for 500-kv, the ordinate should be computed by the relation.

$$S_{1000} = \frac{9\,d^2\,D^2}{i} \times 10^{-5}$$

(The 500-kv absorption curve is used to determine the barrier thickness). For

2000-kvp, the output is 60 times larger than that for 500-kv, and the ordinate (the 500-kv absorption curve is used to determine the barrier thickness) should be obtained from the relation

$$S_{2000} = \frac{1.5\ d^2\ D^2}{i} \times 10^{-5}$$

The amount of direct (leakage) radiation is considerably reduced by the protection incorporated in the tube housing. Most manufactures have incorporated sufficient barrier in the tube housing to reduce the direct radiation to a maximum of 1 r/hr (0.017 r/min) at 1 m from the target for therapeutic-type tube housings, and to 0.10 r/hr (0.0017 r/min) at 1 m from the target for diagnostic-type tube housings. These radiation levels are for the maximum rated current for the maximum rated x-ray tube potential. The extra attenuation required may be determined from the table on page 156.

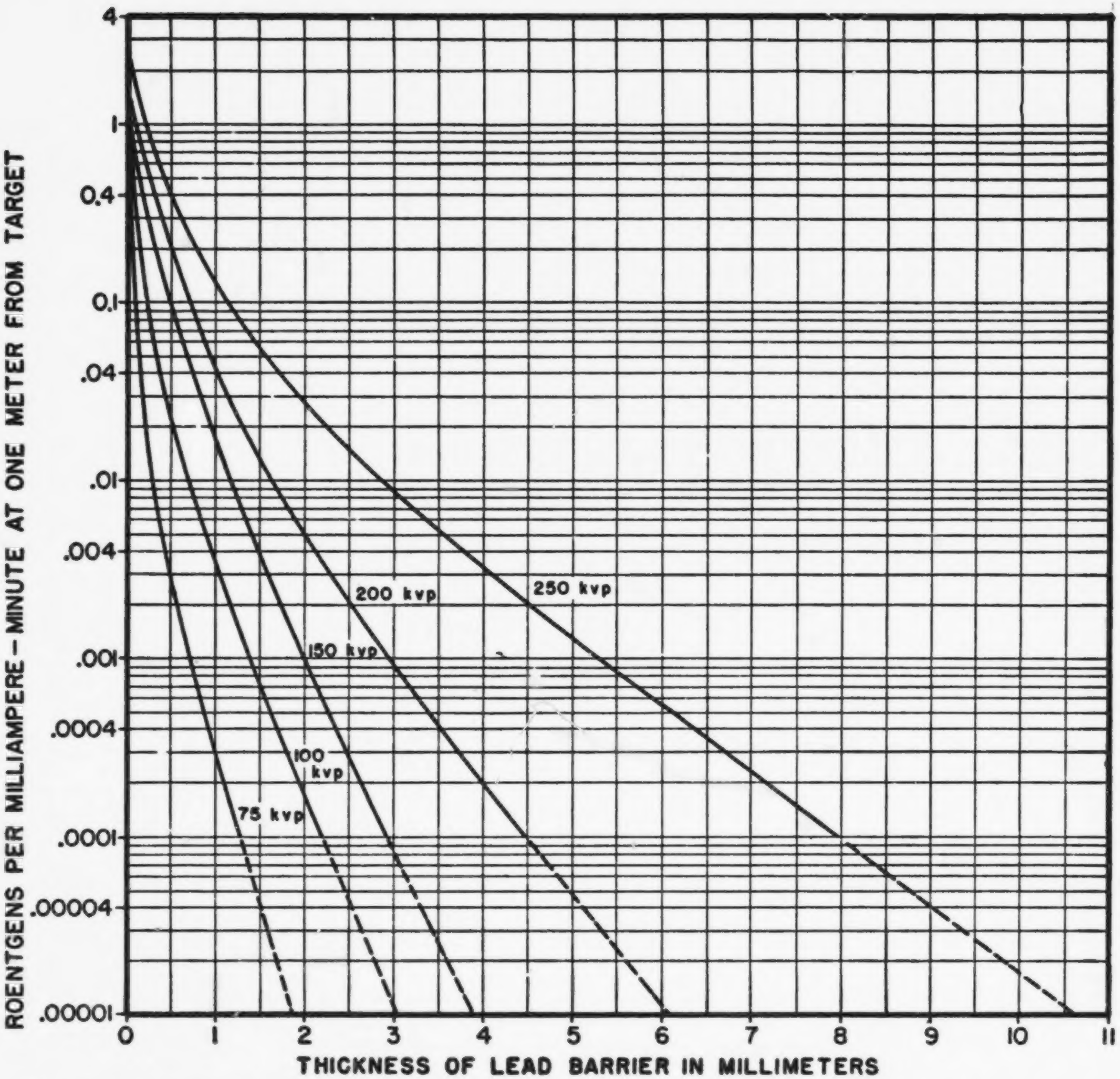
If the barrier thicknesses computed for scattered radiation and for direct (leakage) radiation are nearly equal (or differ by less than 3 HVL), then 1 HVL of lead should be added to the larger single-barrier thickness to obtain the required total for the secondary barrier. But if one of the thicknesses is more than 3 HVL greater than the other, the thicker one alone is adequate.

APPROXIMATE HALF-VALUE LAYERS AT DIFFERENT X-RAY TUBE POTENTIALS

Tube Potential	Half-Value Layer	Filtration
75	0.18 mm Pb	0.5 mm Al
100	0.24 mm Pb	0.5 mm Al
150	0.30 mm Pb	3.0 mm Al
200	0.50 mm Pb	3.0 mm Al
250	0.80 mm Pb	3.0 mm Al
400	2.0 mm Pb	0.4 mm Sn; 0.75 mm Cu; 2.0 mm Al
500	3.0 mm Pb, or 1.5 in Concrete	2.8 mm W; 2.8 mm Cu; 2.1 mm brass; 1.87 mm H_2O
1000	8.0 mm Pb, or 1.8 in Concrete	2.8 mm W; 2.8 mm Cu; 2.1 mm brass; 1.87 mm H_2O
2000	2.3 in Concrete	1.6 mm W; 5.1 mm Cu; 6.8 mm H_2O

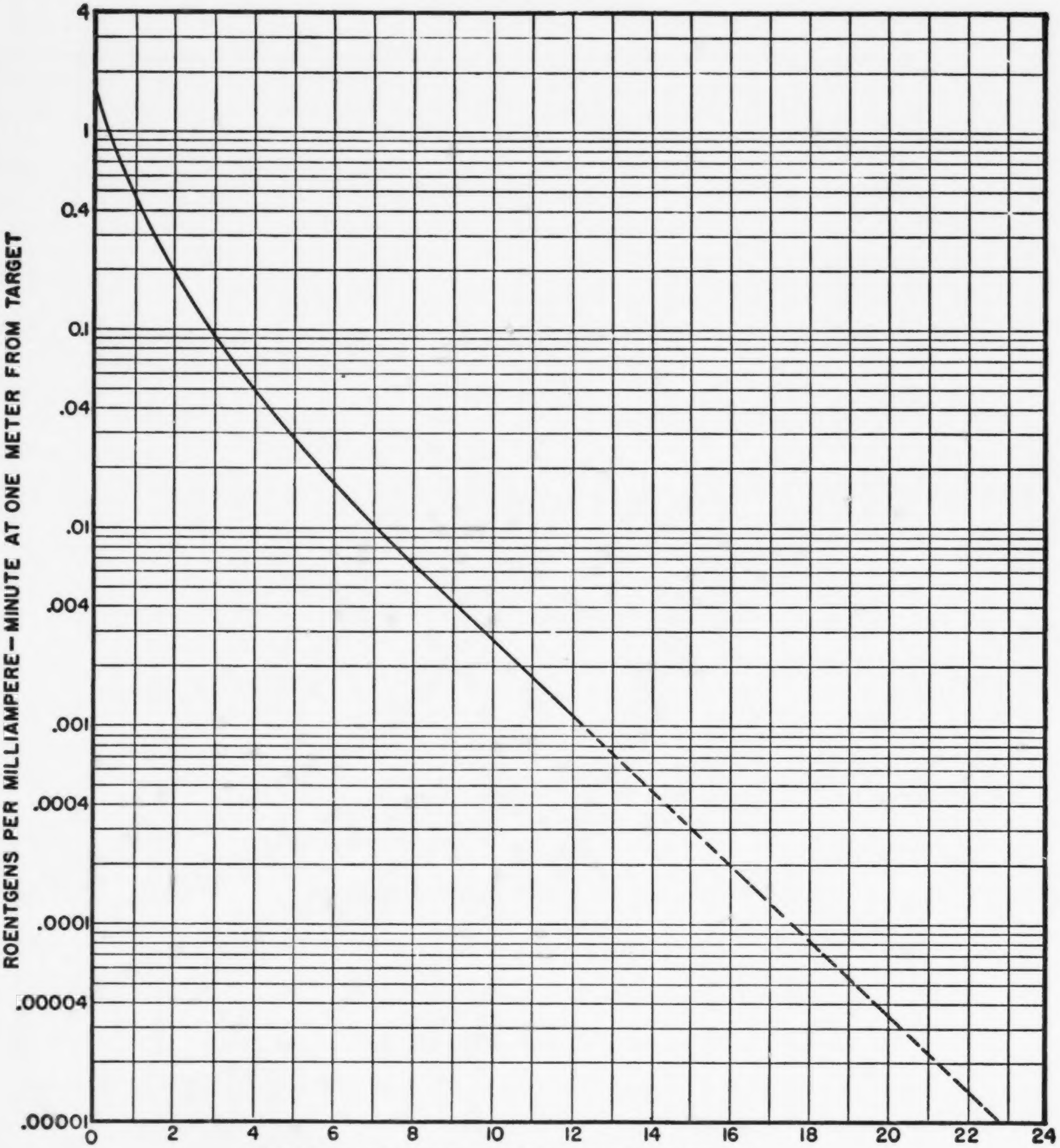
All tube potentials, except 1000-kv and 2000-kv, are pulsating potentials with reflection targets. The 1000-kv and 2000-kv potential are constant potentials with transmission targets. Concrete density is 147 lb/ft^3. Data from NBS Handbook 50.

Attenuation in lead of X-rays produced by potentials of 75- to 250-kvp.



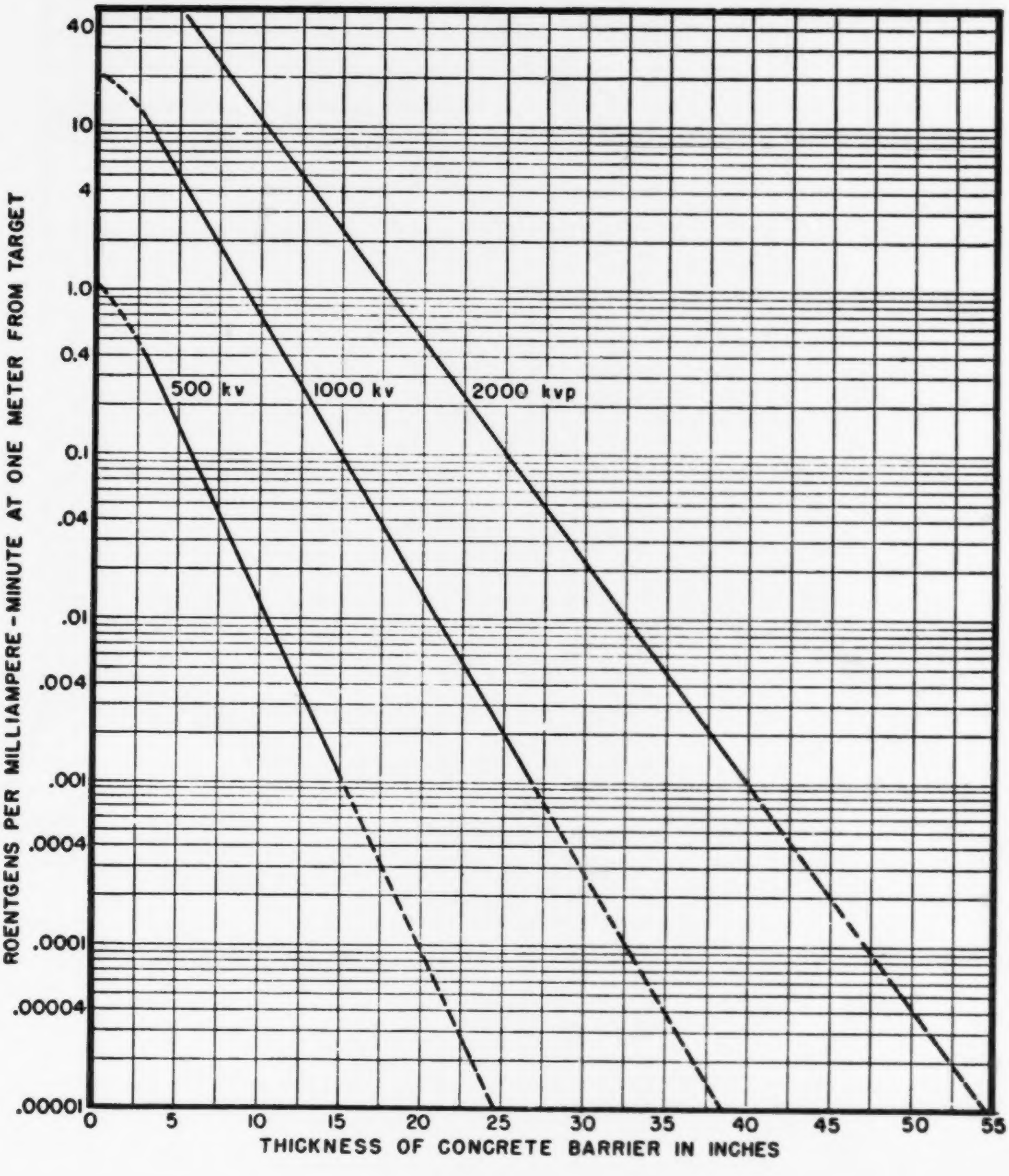
The curves were obtained with a half-wave generator and with a 90-degree angle between the electron beam and the axis of the X-ray beam. The filter was 3 mm of aluminum for the 150-, 200-, and 250-kvp curves and 0.5 mm of aluminum for the 75- and 100-kvp curves. Direct-current potentials require 10-percent-thicker barriers than for the pulsating potentials given above Data from NBS Handbook 50

Attenuation in lead of X-rays produced by a potential of 400 kvp.



The curves were obtained with a half-wave generator and with a 90-degree angle between the electron beam and the axis of the X-ray beam. The filter was 0.4 mm of tin, 0.75 mm of copper, 2 mm of aluminum, plus the inherent filtration of the tube from NBS Handbook 50

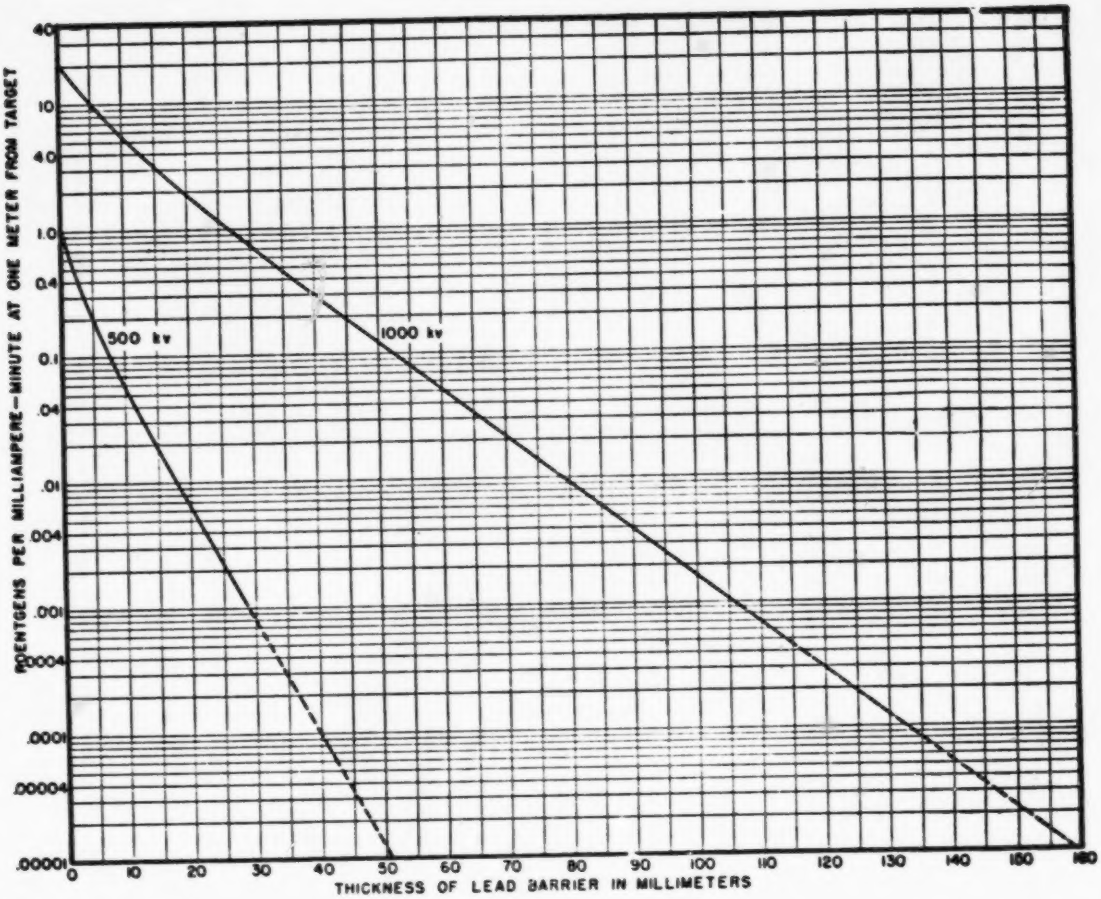
Attenuation in concrete of X-rays produced by potentials of 500 kv, 1,000 kv, and 2,000 kvp.



The 500- and 1,000-kv curves were obtained with a direct-current generator [5]; the 2,000 kvp was obtained with a resonance generator [6]. All data were obtained with an angle of zero degree between the electron beam and the axis of the X-ray beam. The filter at 500 and 1,000 kv was 2.8 mm of tungsten, 2.8 mm of copper, 2.1 mm of brass, and 18.7 mm of water; and at 2,000 kvp was 1.6 mm of tungsten, 5.1 mm of copper, and 6.8 mm of water. If the density of the concrete used in an installation is different from that of the above curves (147 lb/ft^3), the abscissa should be corrected by a factor of 147 divided by the density of the concrete used.

Data from NBS Handbook 50

Attenuation in lead of X-rays produced by potentials of 500 and 1,000 kv.



The curves were obtained with a direct-current generator and with an angle of zero degree between the electron beam and the axis of the X-ray beam. The inherent filtration was 2.8 mm of tungsten, 2.8 mm of copper, 2.1 mm of brass, and 18.7 mm of water

Data from NBS Handbook 50

Half-Value Layers of Protective Material Required to Reduce the Leakage Radiation to the Permissible Level*

Distance	No. Half-Value Layers		Distance	No. Half-Value Layers	
	Diagnostic Tube	Therapeutic Tube		Diagnostic Tube	Therapeutic Tube
3	4.2	7.5	12	0	3.6
4	3.4	6.7	15	-	2.9
5	2.8	6.1	17	-	2.6
6	2.3	5.5	20	-	2.1
7	1.8	5.1	25	-	1.5
8	1.5	4.7	30	-	0.9
9	1.0	4.3	40	-	0
10	0.8	4.1			

---

* This presupposes that the tube is surrounded by an adequate tube shield, and hence the table represents additional barrier requirements. Data from NBS Handbook 50.

CONCRETE EQUIVALENTS OF LEAD AT DIFFERENT X-RAY TUBE POTENTIALS

Lead Thickness	Tube Potential			
	150 kvp	200 kvp	300 kvp	400 kvp
	Millimeters of Concrete*			
mm				
1	80	75	56	47
2	150	140	89	70
3	220	200	117	94
4	280	260	140	112
6	---	---	200	140
8	---	---	240	173
10	---	---	280	210
15	---	---	---	280

* Density 2.35 g/cm^3. Data from NBS Handbook 50.

IRON EQUIVALENTS OF LEAD AT DIFFERENT X-RAY TUBE POTENTIALS

Lead Thickness	Tube Potential						
	150 kvp	200 kvp	300 kvp	400 kvp	600 kvp	800 kvp	1000 kvp
	Millimeters of Iron						
mm							
1	11	12	12	11	10	9	8
2	25	27	20	18	16	14	13
3	37	40	28	23	19	17	16
4	50	55	35	28	23	20	18
6	---	---	48	38	30	26	23
8	---	---	60	45	36	31	28
10	---	---	75	55	42	36	32
15	---	---	---	75	55	48	43
20	---	---	---	---	70	60	55
50	---	---	---	---	---	125	110

Data from NBS Handbook 50

NOMOGRAM FOR DOSAGE RATE DETERMINATIONS IN DIAGNOSTIC ROENTGENOLOGY

EXAMPLE OF USE

Diagnostic Fluoroscope

Given:

Peak tube kilovoltage	75 kvp
Tube Current	3 ma
External filtration	1 mm Al
Target - Skin Distance	15 inches

Find: Dosage rate in air, in roentgens per minute.

Solution: Place a straightedge connecting 75 kvp with 1 mm. Al, in first column, with 15 inches target - skin distance, in second column.

Read from third column:
Dosage rate in air = 55 mr/mas
(milliroentgens per milliampere-second)

Time = 1 minute = 60 seconds

Current = 3 milliamperes

Milliampere-seconds/min = 3 x 60 = 180 mas/min

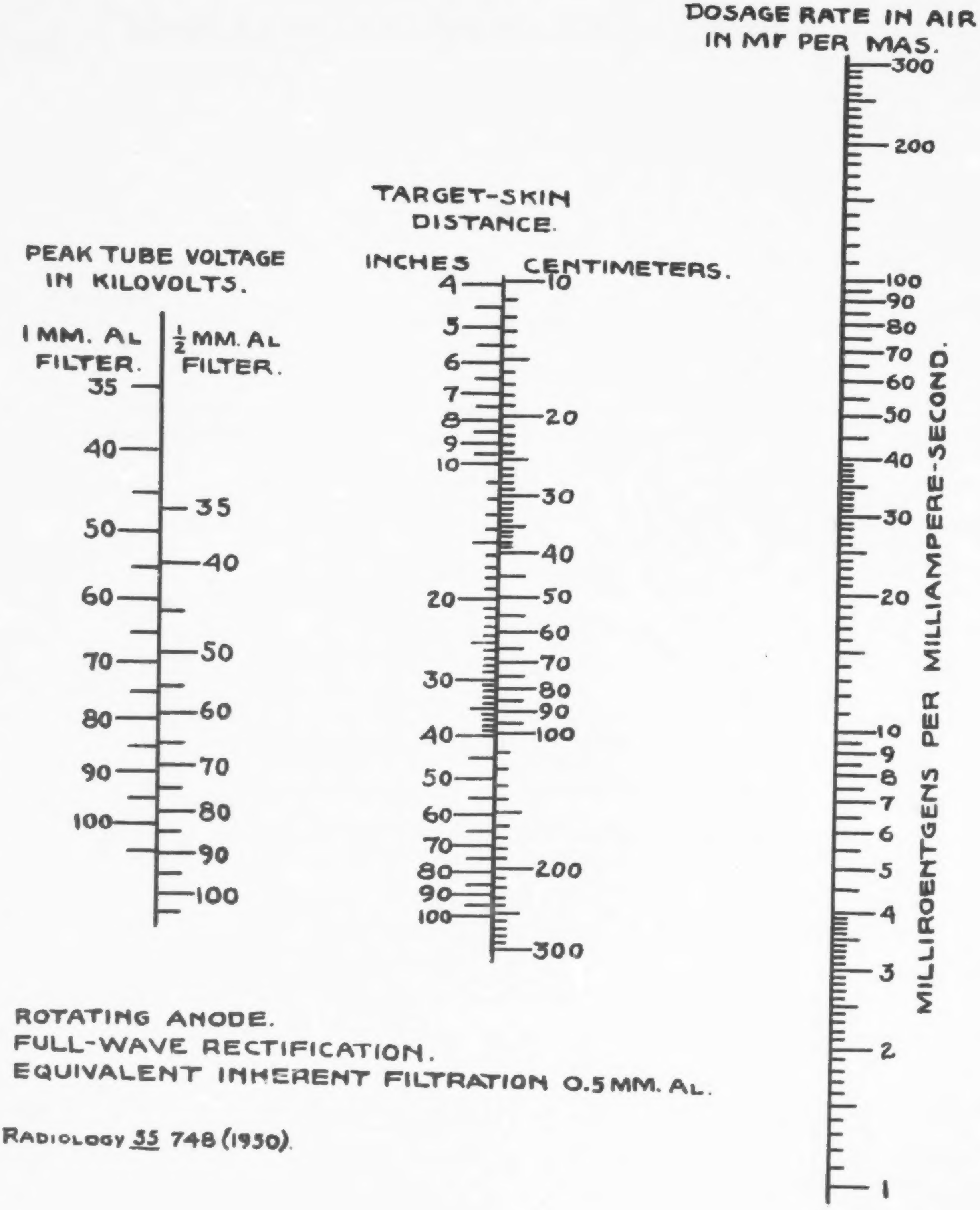
Dosage rate in air = (55 mr/mas) x (180 mas/min)

= 9,900

= 9.9 roentgens per minute (r/min)

The nomogram in its present form can be used directly for many different types of x-ray machines which have added filters of 0.5 or 1.0 mm Al. For added filter of 1.5 mm Al, the dosage rate will be approximately 11 percent less than the values given for 1.0 mm Al for 65-kv to 105-kv. The roentgen dose in air at the skin given by the nomogram should be correct, for a given machine, to within ± 25 percent. In all cases the dosage rate is given in air at the skin.

NOMOGRAM FOR DOSAGE RATE DETERMINATIONS IN DIAGNOSTIC ROENTGENOLOGY.



ROTATING ANODE.
FULL-WAVE RECTIFICATION.
EQUIVALENT INHERENT FILTRATION 0.5 MM. AL.

RADIOLOGY 55 748 (1950).

X-RAY EXPOSURE - EXPOSURE RATE RELATIONSHIPS

Examples of Use

Example 1.

Given: Exposure rate.................................. 1,080 mr/hr
Time of Exposure............................. 1 second

Find: Total exposure

Solution: Place a straightedge connecting 1 second, in second column, with 1,080 mr/hr, in the third column.

Read from fourth column:
total exposure = 0.3 mr

Example 2.

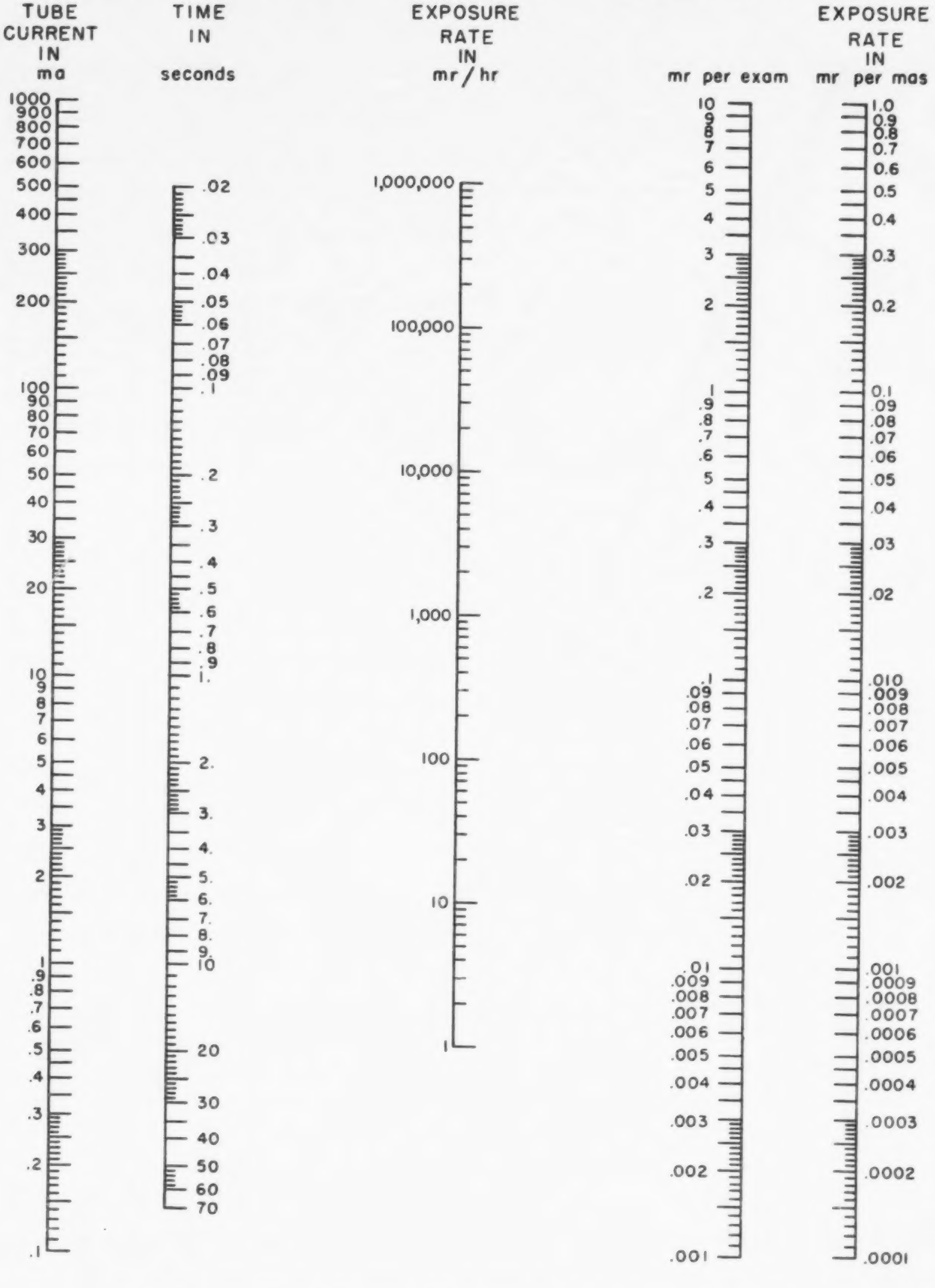
Given: Tube current in the problem above is 50 ma

Find: Exposure rate in mr per mas

Solution: Place straightedge connecting 50 ma in the first column, and 1,080 mr/hr in the third column.

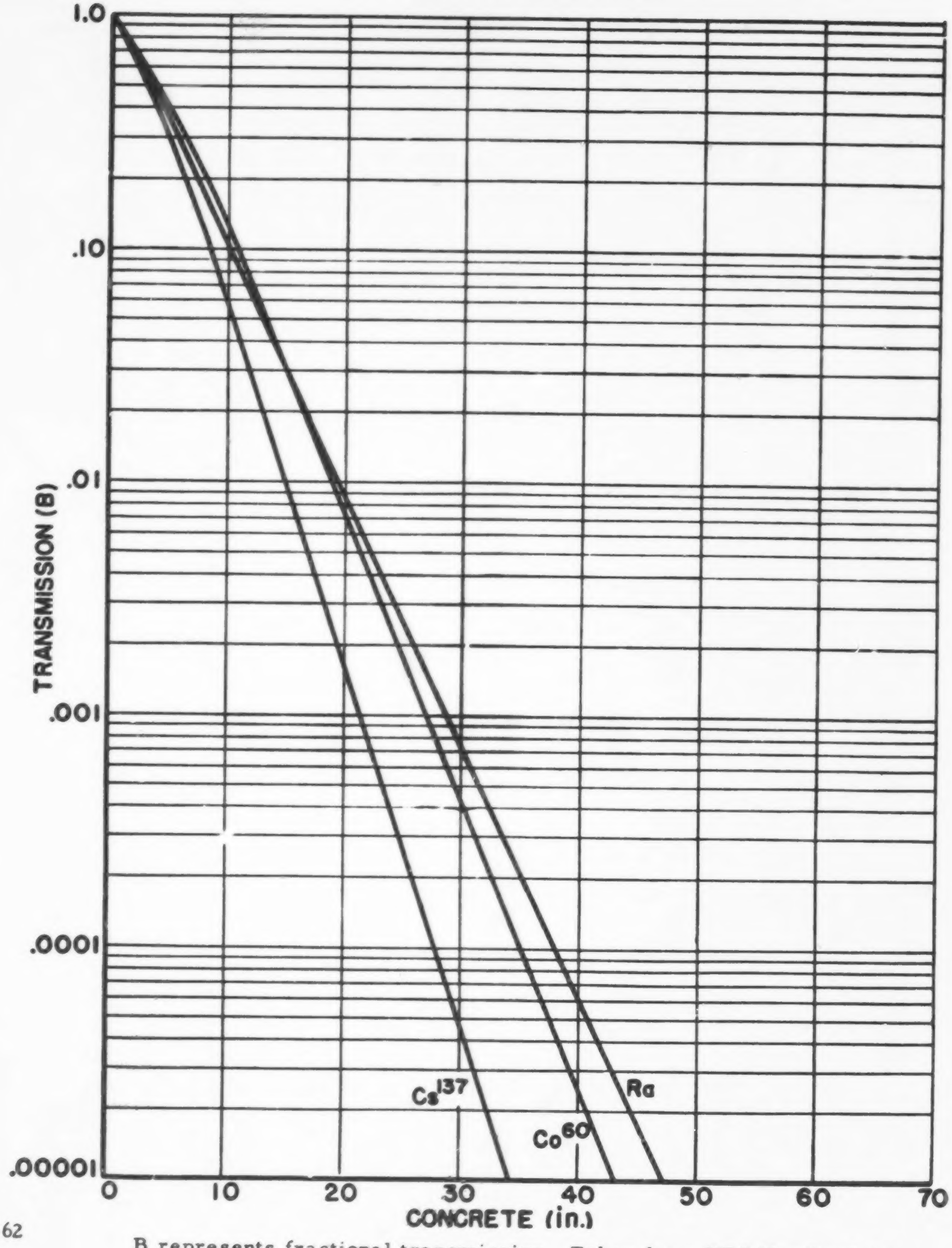
Read from fifth column:
Exposure rate = .006 mr/mas

X-RAY EXPOSURE — EXPOSURE RATE RELATIONSHIP *



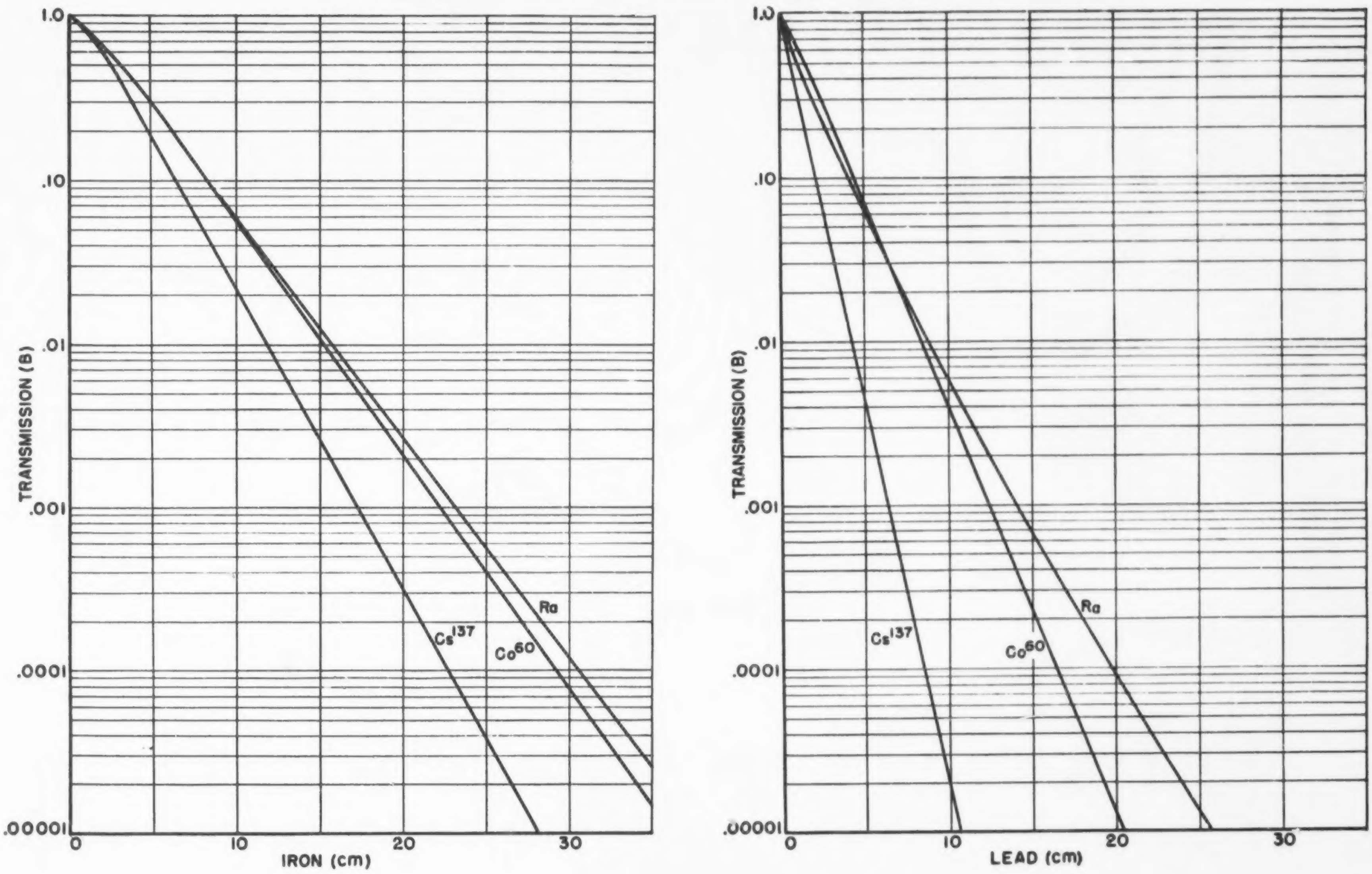
* PREPARED BY P. J. VALAER OF THE U.S. PUBLIC HEALTH SERVICE

TRANSMISSION OF RADIUM, COBALT-60 AND CESIUM-137 GAMMA RAYS



B represents fractional transmission. Taken from NBS Handbook 54.

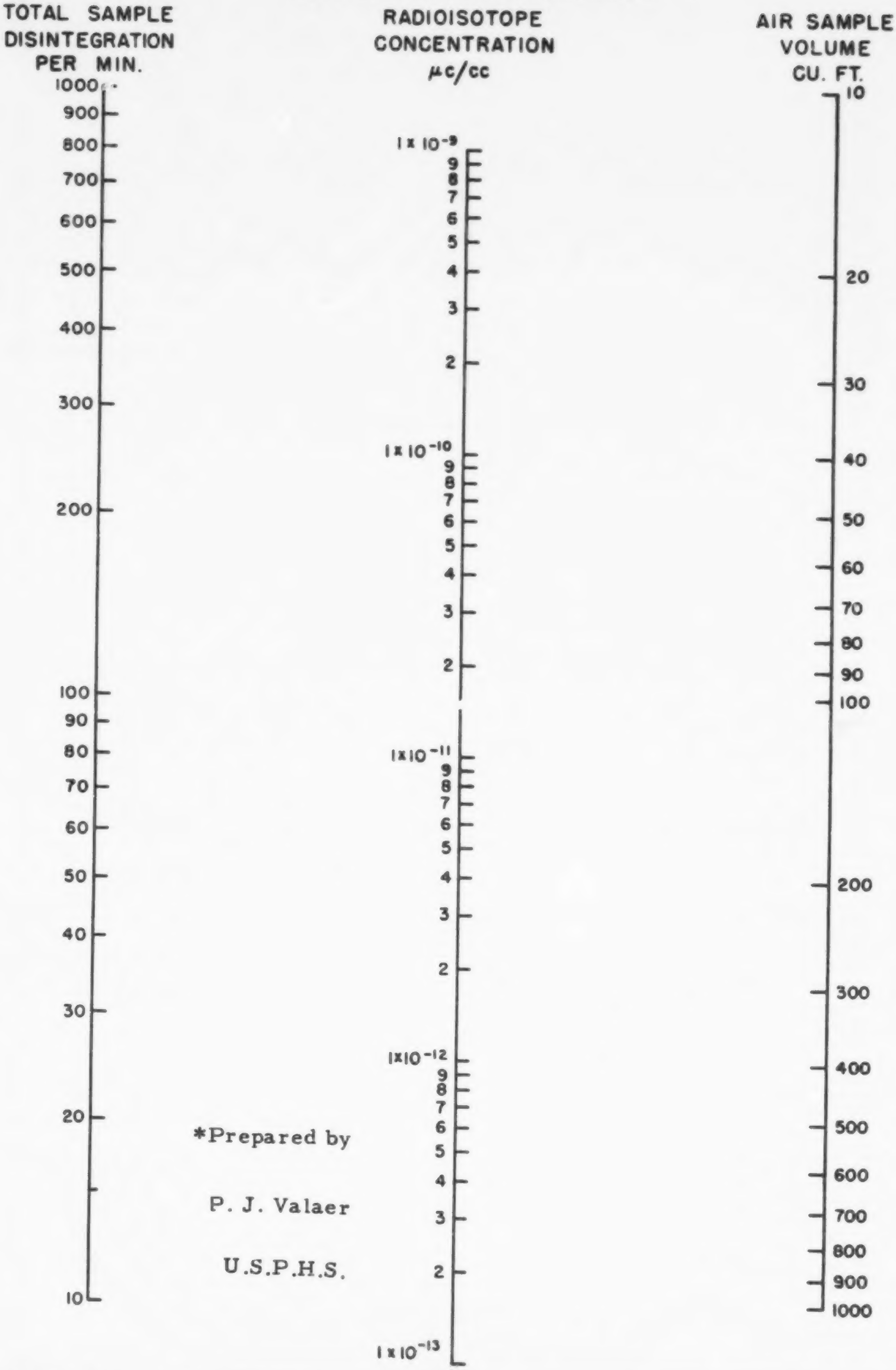
TRANSMISSION OF RADIUM, COBALT-60 AND CESIUM-137 GAMMA RAYS



B represents fractional transmission. Taken from NBS Handbook 54.

NOMOGRAM

SAMPLING OF AIR CONTAINING RADIOACTIVE CONTAMINANTS *


TOTAL SAMPLE DISINTEGRATION PER MIN.
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
RADIOISOTOPE CONCENTRATION μc/cc
1 x 10⁻⁹
9
8
7
6
5
4
3
2
1 x 10⁻¹⁰
9
8
7
6
5
4
3
2
1x10⁻¹¹
9
8
7
6
5
4
3
2
1x10⁻¹²
9
8
7
6
5
4
3
2
1 x 10⁻¹³
AIR SAMPLE VOLUME CU. FT.
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000

*Prepared by

P. J. Valaer

U.S.P.H.S.

THE STANDARD MAN*

1. MASS OF ORGANS

Organs	Grams	Organs	Grams
Muscles	30,000	Brain	1,500
Skeleton:		Spinal cord	30
Bones	7,000	Bladder	150
Red marrow	1,500	Salivary glands	50
Yellow marrow	1,500	Eyes	30
Blood	5,000	Teeth	20
Gastrointestinal tract	2,000	Prostate	20
Lungs	1,000	Adrenals	20
Liver	1,700	Thymus	10
Kidney	300	Skin and subcutaneous tissues	8,500
Spleen	150		
Pancreas	70	Other tissues and organs not separately defined	8,390
Thyroid	20		
Testes	40		
Heart	300		
Lymphoid tissue	700	Total Body Weight	70,000

2. CHEMICAL COMPOSITION

Element	Proportion	Approximate mass in the body
	Percent	g
Oxygen	65.0	45,500
Carbon	18.0	12,600
Hydrogen	10.0	7,000
Nitrogen	3.0	2,100
Calcium	1.5	1,050
Phosphorus	1.0	700
Potassium	0.35	245
Sulfur	.25	175
Sodium	.15	105
Chlorine	.15	105
Magnesium	.05	35
Iron	.004	3
Manganese	.0003	0.2
Copper	.0002	0.1
Iodine	.00004	0.03

The figures for a given organ may differ considerably from these averages for the whole body. For example, the nitrogen content of the dividing cells of the basal layer of skin is probably nearer 6 percent than 3 percent.

---

* As stated in U.S. Department of Commerce, Bureau of Standards Handbook 47, 1950, Appendix I.

3. APPLIED PHYSIOLOGY

Average data for normal activity in a temperate zone:

(1) Water balance:

DAILY WATER INTAKE

In food (including water of oxidation)	1.0 liter
As fluids	1.5 liters
Total	2.5 liters

Calculations of maximum permissible levels for radioactive isotopes in water have been based on the total intake figure of 2.5 liters a day.

DAILY WATER OUTPUT

Sweat	0.5 liter
From Lungs	0.4 liter
In feces	0.1 liter
Urine	1.5 liters
Total	2.5 liters

(The total water content of the body is 50 liters)

(2) Respiration:

AREA OF RESPIRATORY TRACT

Respiratory interchange area	$50m^2$
Nonrespiratory area (upper tract and trachea to bronchioles)	$20m^2$
Total	$70m^2$

RESPIRATORY EXCHANGE

Physical activity	Hours per day	Tidal air (liters)	Respiration per minute	Volume per 8 hours, m^3	Volume per day, m^3
At work	8	1.0	20	10	20
Not at work	16	0.5	20	5	20

CARBON DIOXIDE CONTENT (BY VOLUME) OF AIR

Inhaled air (dry, at sea level)	0.03%
Alveolar air	5.5%
Exhaled air	4.0%

(3) Retention of particulate matter in the lungs:

In those cases where specific data are lacking, the convention has been adopted that 50 percent of any aerosol reaches the alveoli of the lungs. If the particles are soluble, they have been considered to be completely absorbed; if insoluble, then the 50 percent amount has been regarded as retained for 24 hours, after which only half of it, that is, 25 percent of the inhaled amount, is retained in situs indefinitely.

4. DURATION OF EXPOSURE

(1) Duration of occupational exposure:

The following figures have been adopted in calculations pertaining to occupational exposure:

8 hours per day
40 hours per week
50 weeks per year

(2) Duration of "lifetime" for nonoccupational exposure

A conventional figure of 70 years has been adopted.

****

RELATIVE AND ABSOLUTE VALUES FOR LEUKOCYTE COUNTS IN NORMAL ADULTS PER CUBIC MILLIMETER OF BLOOD*

		Absolute Number		
Type of Cell	Percent	Average	Minimum	Maximum
Total leukocytes..........	---	7,000	5,000	10,000
Myelocytes.................	0	0	0	0
Juvenile neutrophils.....	3-5	300	150	400
Segmented neutrophils..	54-62	4,000	3,000	5,800
Eosinophils	1-3	200	50	250
Basophils...................	0-0.75	25	15	50
Lymphocytes	25-33	2,100	1,500	3,000
Monocytes..................	3-7	375	285	500

BLOOD COUNT

NORMAL RANGE OF VALUES - HUMAN ADULTS*

	Male	Female
Red Cell Count (millions per cu.mm)	5.4 ± 0.8	4.8 ± 0.6
Hemoglobin (gm. per 100 cc.)	16.0 ± 2.0	14.0 ± 2.0
Hematocrite or Vol. packed R. B. C. (cc. per 100 cc.)	47.0 ± 7.0	42.0 ± 5.0

---

* M. M. Wintrobe, Clinical Hematology, Lea & Febiger, Philadelphia, Third Edition.

PROBABLE EARLY EFFECTS OF ACUTE RADIATION DOSES OVER WHOLE BODY*

Acute Doses	Probable Effect
0-25 r	No obvious injury
25-50 r	Possible blood changes but no serious injury
50-100 r	Blood-cell changes, some injury, no disability
100-200 r	Injury, possible disability
200-400 r	Injury and disability certain, death possible
400 r	Fatal to 50 percent
600 or more r	Fatal

SUMMARY OF EFFECTS RESULTING FROM WHOLE BODY EXPOSURE TO RADIATION

Time After Exposure	Lethal Dose (600 r)	Median Lethal Dose (400 r)	Moderate Dose (300 to 100 r)
First Week	Nausea and vomiting after 1-2 hours No definite symptoms Diarrhoea Vomiting Inflammation of mouth & throat	Nausea and vomiting after 1-2 hours No definite symptoms	No definite symptoms
Second Week	Fever Rapid emaciation (Mortality probably 100%)		
Third Week		Beginning epilation Loss of appetite and general malaise Fever Severe inflammation of mouth & throat	Epilation Loss of appetite and general malaise
Fourth Week		Pallor Petechiae, diarrhoea and nosebleeds Rapid emaciation Death (Mortality probably 50%)	Sore throat Pallor Petechiae Diarrhoea Moderate emaciation (Recovery likely unless complicated by poor previous health or superimposed injuries or infections)

---

* "The Effects of Atomic Weapons", U.S. Government Printing Office.

ESTIMATE OF EFFECTIVE DOSE AND LETHALITY OF VARIOUS DOSE RATES*

Day	Accumulated Dose (r)	Effective Accumulated Dose (r)	Estimated Mean Survival Time (Days)	Estimated percent Deaths in 30 days
200 r/day				
1	200	200	--	30
3	600	542	20	60
5	1000	819	15	85
10	2000	1326	10	100
100 r/day				
1	100	100	--	8
3	300	271	--	35
5	500	409	15	50
10	1000	663	15	75
50 r/day				
1	50	50	--	0
3	150	135	--	15
5	250	204	30	25
10	500	330	30	40
15	750	395	30	50

ESTIMATED DOSES FOR VARYING DEGREES OF INJURY*

Accumulated Dose (r) or Dose Rate	Period of Time	Effect
500 r/day	2 days	Mortality close to 100%
100 r/day	Until Death	Mean survival time approximately fifteen days. 100% mortality in 30 days.
60 r/day	10 days	Morbidity and mortality high with crippling disabilities.
30 r/day	10 days	Disability, moderate.
10 r/day	365 days	Some deaths.
3 r/day	Few months	No drop in efficiency.
0.5 r/day	Many months	No large scale drop in life span.

---

* Based on 250 kvp x-rays. Corrections should be made for higher energy radiations. e.g. 1000 kvp x-or gamma radiation would have a relative biological effectiveness of approximately 70% of 250 kvp x-rays.

SECTION V

APPENDIX

Introduction to Table of Isotopes . . . . pages App. i-viii
Table of Isotopes . . . . pages App. 1-137
Rapid Method for Calculating Log (f t) Values . . . . . . pages App. 138-141

APPENDIX

TABLE OF ISOTOPES

by

J. M. Hollander, I. Perlman, and G. T. Seaborg

Permission to reproduce the "Table of Isotopes" as an appendix to the Radiological Health Handbook was granted by the authors, J. M. Hollander, I. Perlman and G. T. Seaborg and the Publishers, Reviews of Physics. The photographic negatives used in the reproduction were loaned to the Public Health Service by the University of California Radiation Laboratory.

Special notation is made of the third paragraph page i of the preface to these tables. This section describes the parenthetical references such as (16H41) (16H41a) and (16H41b), which follow the data in various columns of the table. These entries are code symbols given to the authors of papers which appear in a lengthy bibliography normally printed in conjunction with the "Table of Isotopes" as it was in the original publications. This bibliography has been omitted from the Radiological Health Handbook for economic reasons but may be found on pages 613-651 of Vol. 25, No. 2, April 1953, Reviews of Modern Physics.

ALPHABETICAL INDEX OF ELEMENTS IN "TABLE OF ISOTOPES"

Element	Symbol	Z No.	Page Number
Actinium	Ac	89	125
Aluminum	Al	13	7
Americium	Am	95	134
Antimony	Sb	51	65
Argon	A	18	11
Arsenic	As	33	30
Astatine	At	85	121
Barium	Ba	56	79
Berkelium	Bk	97	137
Beryllium	Be	4	2
Bismuth	Bi	83	117
Boron	B	5	2
Bromine	Br	35	33
Cadmium	Cd	48	57
Calcium	Ca	20	13
Californium	Cf	98	137
Carbon	C	6	2
Cerium	Ce	58	83
Cesium	Cs	55	76
Chlorine	Cl	17	10
Chromium	Cr	24	17
Cobalt	Co	27	20
Copper	Cu	29	23
Curium	Cm	96	136
Dysprosium	Dy	66	92
Erbium	Er	68	94
Europium	Eu	63	89
Fluorine	F	9	5
Francium	Fr	87	124
Gadolinium	Gd	64	91
Gallium	Ga	31	26
Germanium	Ge	32	28
Gold	Au	79	108
Hafnium	Hf	72	98
Helium	He	2	1
Holmium	Ho	67	93
Hydrogen	H	1	1
Indium	In	49	59
Iodine	I	53	70
Iridium	Ir	77	105
Iron	Fe	26	19
Krypton	Kr	36	35
Lanthanum	La	57	81
Lead	Pb	82	114
Lithium	Li	3	1
Lutecium	Lu	71	97
Magnesium	Mg	12	7
Manganese	Mn	25	18
Mercury	Hg	80	110
Molybdenum	Mo	42	47
Neodymium	Nd	60	86
Neon	Ne	10	6
Neptunium	Np	93	131
Nickel	Ni	28	21
* Niobium	Nb	41	45
Nitrogen	N	7	3
Osmium	Os	76	104
Oxygen	O	8	4
Palladium	Pd	46	53
Phosphorus	P	15	9
Platinum	Pt	78	107
Plutonium	Pu	94	133
Polonium	Po	84	120
Potassium	K	19	12
Praseodymium	Pr	59	85
Promethium	Pm	61	87
Protoactinium	Pa	91	128
Radium	Ra	88	124
** Radon	Rn	86	123
Rhenium	Re	75	103
Rhodium	Rh	45	51
Rubidium	Rb	37	37
Ruthenium	Ru	44	50
Samarium	Sm	62	88
Scandium	Sc	21	14
Selenium	Se	34	31
Silicon	Si	14	8
Silver	Ag	47	54
Sodium	Na	11	6
Strontium	Sr	38	40
Sulfur	S	16	9
Tantalum	Ta	73	100
Technetium	Tc	43	48
Tellurium	Te	52	67
Terbium	Tb	65	92
Thallium	Tl	81	113
Thorium	Th	90	126
Thulium	Tm	69	95
Tin	Sn	50	63
Titanium	Ti	22	15
Uranium	U	92	129
Vanadium	V	23	16
*** Wolfram	W	74	101
Xenon	Xe	54	73
Ytterbium	Yb	70	96
Yttrium	Y	39	41
Zinc	Zn	30	24
Zirconium	Zr	40	43

*Formerly Columbium (Cb)
**Listed herein as Radium Emanation, Symbol Em
***Also called Tungsten

#1-a

TABLE OF ISOTOPES

J. M. Hollander, I. Perlman, and G. T. Seaborg
Department of Chemistry and Radiation Laboratory
University of California, Berkeley, California

December 1952

The following table represents a complete list of all the radioactive and stable isotopes of the elements, together with a number of their salient features, as recorded in the literature or by private communication by approximately December 1952.

A primary objective has been to retain as much of the compactness of the previous editions as is consistent with an adequate coverage of the multitudes of nuclear data presently available.

A new system of references has been employed. Each paper is represented by the code symbol of the first author, followed by the year in which the paper was published. If two or more papers by one author have appeared during a single year, these are distinguished by the small letters a, b, c, etc. following the main reference. For example, 16H is the code symbol given to O. Hahn; thus, the references 16H41, 16H41a, and 16H41b represent three papers published in 1941 of which O. Hahn is the first author. The code symbols given to the authors are arranged alphabetically only with respect to the first letter of their names.

A description of the entries in the various columns is given below, followed by a table listing some frequently used abbreviations.

ISOTOPE

The first column lists the atomic numbers, chemical symbols, and mass numbers of the nuclear species. Separate entries have been made for each nuclear state whose half-life has been experimentally determined. Metastable excited states are denoted by the superscript "m" following the mass number, and for those cases in which two or more isomeric states are known, they are distinguished by the use of the superscripts "m_1", "m_2", etc.

CLASS AND IDENTIFICATION

The degree of certainty of each isotopic assignment is indicated by a letter, according to the following code:

A Element and mass number certain
B Element certain and mass number probable
C Element probable and mass number certain or probable
D Element certain and mass number not well established
E Element probable and mass number not well established or unknown (mass number not listed means that it is unknown)
F Insufficient evidence
G Assignment probably in error

Data which have been shown to be in error have in general been eliminated from the table. A few isotopes have been quoted so widely in the literature, however, that it was felt some reference should be made to them. For these cases the G rating has been adopted, and reference made both to the original work and to that which has supplanted it.

The means by which the mass assignments were made are next tabulated. In general, several references are given here, the first of which denoted the probable discoverer of the isotope (except in the cases of the old natural radioactivities). Following this, references are given to the paper or papers which contributed most significantly toward giving the isotope its best or present rating. Some indication of the experimental methods used in making the various assignments may be had from the following symbolism:

chem	Chemical separations, establishing uniquely the chemical identity (atomic number) of the isotope
genet	Proven genetic relationships (by chemical or other means) with other isotopes whose mass assignments are presumably known
genet energy levels	Proof of isobaric relationship with an identified nuclide by observation of identical energy levels following decay of both, implying decay to the same product
excit	Loosely refers to energetic considerations which have aided in making the mass assignment. Some of these might be: (1) Excitation or yield experiments to establish the nuclear reaction which produces the isotope (2) Bombardments with low energy particles, in which possible products are few (3) Mass calculations, or other estimates or measurements of Q values (4) In a few cases, use of fission yield data in making assignments
cross bomb	Studies of yields of the isotope in several different types of bombardments, in which the target elements as well as the projectiles have been varied
n-capt	Cases where bombardments with slow neutrons (n-γ reactions) have provided key evidence in the mass assignments
sep isotopes	The use of target elements enriched or depleted in a certain isotope
mass spect	Identification of the mass number by means of a mass spectrograph
resonance neutron activation	Identification of a nuclear isomer by observing both isomers upon irradiation with filtered neutrons
decay charac	Identification of expected or predicted decay characteristics

PERCENT ABUNDANCE

The relative isotopic abundances for the elements are given in accordance with the "best values" listed in the report (1B50) by K. T. Bainbridge and A. O. Nier. In some of the light elements, reference is made also to papers which discuss source variations in isotope abundances.

TYPE OF DECAY

The observed modes of decay have been listed for all radioactive nuclei. In cases of branched decay between two or more modes, the branching ratios are listed wherever they are known. Symbols used are:

β^-	Negative beta particle (negatron) emission
β^+	Positive beta particle (positron) emission
α	Alpha particle emission
EC	Orbital electron capture. It may be assumed that x-rays have been observed or actually identified in virtually all cases of orbital electron capture listed. If the ratio of L electron capture to K electron capture has been determined, it is given here as L/K.
IT	Isomeric transition (transition from upper to lower isomeric state of same nucleus)
n	Neutron emission

When experimenters have searched for and failed to find a particular mode of decay, this is indicated, for example, as "no β^+". Experimental upper limits are frequently given, but no theoretically predicted limits have been quoted.

Among the heavy alpha emitting isotopes, calculations by means of closed radioactive decay cycles have shown that many of these isotopes are thermodynamically stable against β^-, β^+, or EC decay. This has been indicated by the term "β stable," followed by an abbreviation for the principle of conservation of energy, which is used in the calculations.

HALF-LIFE

Half-life values are listed without qualification where the determination has been a direct measurement of decay rate. In other cases, the experimental methods have been described with the aid of the following symbols:

sp act	Determination by weighing a long lived isotope of known purity
delay coinc	Measurement of the time interval between two successive nuclear events (such as β^- and γ emission) thus establishing the lifetime of the state responsible for the second event. By this method, half-lives between 10^{-3} s and 10^{-10} s have been determined.
yield	Estimation of half-life from the amount of activity resulting from a nuclear reaction whose cross section (or yield) is known or estimated
genet	Measurement of the half-life of a parent activity by determining the yield of a daughter activity as a function of time, where periodic chemical separations of daughter from parent have been performed

An attempt has been made to list the best value or values first. However, in a few cases where many values of comparable precision have been reported, and no choice seemed obvious, an average value for the half-life has been listed; this is explicitly stated, and references are given to all the papers whose values contributed to that average. Also, among the natural radioactivities an average value is often used which was taken from an international committee summary report (1C31).

PARTICLE ENERGIES

The particle energies are followed by other relevant information pertaining to the decay scheme, and by a description of the experimental methods used in obtaining the data. In cases of complex alpha structure or several partial beta spectra, the relative abundances of the various groups within that mode of decay are given in parentheses.

Beta particle energies correspond to the upper limits of the spectra.

Alpha particle energies have been quoted only where the investigator has actually measured them. Where he has determined only the relative abundances of alpha groups or the energy differences between groups, this has been indicated as in the example:

$$\alpha_0\ (10\%),\ \alpha_{50}\ (75\%),\ \alpha_{80}\ (15\%)$$

meaning that 75 percent of the alpha particles lead to a state 50 kev above the ground state, and that 15 percent of the alpha particles lead to a state 80 kev above the ground state.

The term "long range α" is the classical designation for alpha particle groups emitted from excited states of the listed nuclide, and the energies therefore are not included in the Q_α value, which applies to the ground state to ground state transition. These alpha groups occur in competition with gamma ray emission, following the beta decay of the parent nuclide.

Conversion electron energies are listed only when it is not known in which shell internal conversion takes place or when no attempt was made by the experimenter to relate the electrons with observed or unobservable gamma rays; in all other cases, entries are made in the column for gamma transitions.

Experimental methods are described as follows:

abs	Absorption
spect	Magnetic deflection (magnetic spectrograph or spectrometer or counter with magnetic field)
scint spect	Measurement of pulses produced by a scintillating crystal or solution
ion ch	Measurement of pulse sizes in ionization chamber or proportional counter
cl ch	Cloud chamber (with magnetic field in case of beta particles)
coinc abs	Beta and gamma coincidence counters with absorbers
coinc spect	Coincidence counters arranged with a spectrometer or spectrometers

GAMMA TRANSITIONS

Gamma transitions are described by the following information, insofar as reliable data permit:

Energy of the gamma quantum. When internal conversion electrons form the basis for the energy determination, the energy listed in this column is always that of the corresponding gamma ray transition.

Abundances of gamma rays. This may be given as the number of unconverted gamma rays emitted per 100 disintegrations. Where an absolute abundance has not been determined, often the relative unconverted gamma ray abundances have been measured. These are tabulated as $\gamma_1/\gamma_2/\gamma_3 = 2/1/5$, for example.

Internal conversion coefficients. These are given for each gamma transition as the ratio of the number of conversion electrons emitted to the number of unconverted gamma quanta emitted, and are expressed as e/γ. Where conversion coefficients for individual electron shells have been determined, they are denoted as e_K/γ, e_L/γ, etc.

Conversion coefficient ratios. Where the ratios of internal conversion coefficients in several electron shells have been measured, they are listed as K/L, L/M, K/L+M, K/L/M, $L_I/L_{II}/L_{III}$, etc.

Gamma rays associated with short lived isomers have been listed as entries both of the isomer and of its parent.

When an author states that gamma radiation is present, but reports no energy determination, this is indicated by the symbol "γ". Conversely, when attempts to find gamma radiation have failed, this has been indicated by "no γ".

X-rays have been mentioned only when they are the prominent radiation observed in measuring an activity, or when the observation and identification of x-rays has been crucial in the characterization of an isotope.

The symbols used to describe the methods employed for the determination of gamma ray energies or for the elucidation of decay schemes are as follows:

spect	Secondary electrons observed with magnetic spectrograph or spectrometer
spect conv	Internal conversion electrons observed with magnetic spectrograph or spectrometer
scint spect	Measurement of pulses produced by a scintillating crystal or solution
cryst spect	Direct measurement by diffraction of gamma rays with a bent crystal spectrometer
abs	Absorption of the gamma rays
abs conv	Absorption of internal conversion electrons
abs sec	Absorption of secondary electrons
coinc	Studies of coincidences or lack of coincidences (γ-γ, γ-conv, conv-conv, β-γ, etc.) with coincidence counters, and, in some cases, spectrometers
coinc abs	Coincidence studies using absorber techniques
cl ch recoil	Secondary electrons observed in cloud chamber with magnetic field
pair spect	Magnetic analysis of positron-electron pairs produced by gamma rays in a thin radiator
Be-γ-n, D-γ-n, or D-γ-p reactions	Measurements of neutron or proton energies from these reactions

DISINTEGRATION ENERGY AND SCHEME

The disintegration energy, or Q value, of a nuclear transformation is defined as the mass difference (expressed in Mev) between the initial and final systems under consideration. For radioactive decay processes, Q is equal to the sum of the particle kinetic energy, nuclear recoil energy, and the energy of any gamma rays necessary to de-excite the final nucleus to its ground state. For positron decay, the energy equivalent to 2 m_0c^2 has been included in the Q value. Where Q values have been estimated or calculated by the authors of this compilation, the special reference "HPS" is used; otherwise, reference is made to the paper from which the quoted value is taken. In most instances Q values have been obtained from decay data; where this is not the case, the method is indicated.

Energy level diagrams have been drawn in many cases; these are not necessarily complete representations of the data, but sometimes include only those features which are reasonably well established and unambiguous. Heights of the various energy levels above the ground state are indicated at the side of the drawing. Similarly, the total angular momentum (spin) and parity of the states have been included in some cases, where these quantum numbers could be inferred with some confidence from determinations of conversion coefficients, K/L ratios, ft values, etc. We have relied heavily on the interpretation of decay data by Goldhaber and Hill (18G52).

For β^-, β^+, α, or EC decay, the percentage figures given in the decay drawings total 100% for each mode of decay, thus expressing only the relative abundances of various groups within that mode of decay. (Branching ratios between the several modes of decay are found in the "Type of Decay" column.) In the case of gamma radiation, however, the percentages given refer to the fraction of the total disintegrations of that isotope which give rise to the gamma ray and its conversion electron. This has been done because of the difficulty of assigning a gamma ray to a particular mode of decay.

Measured values for the mechanical or spin moment I of stable or long lived isotopes have also been given in this column. Except as supplemented by more recent data, the values given here are taken from the compilation by Mack (87M50).

METHOD OF PRODUCTION AND GENETIC RELATIONSHIPS

The observed nuclear reactions (giving the target element, projectile, and outgoing particle, in order) by which the radioactive isotopes are formed, and the corresponding references are listed (p - proton, n - neutron, α - alpha particle, d - deuteron, t - triton, γ - gamma ray or x-ray, e - electron, π - pi meson, C - carbon ion). In cases in which the target material is not the naturally occurring element, but one enriched or depleted in a particular isotope, the isotope responsible for the reaction is indicated. No means for identifying the source or energy of the projectile is given.

In nuclear reactions with high energy projectiles, multiple particle ejection is common. Rather than attempt to state definitely the path by which the product nucleus was reached, these spallation reactions are briefly represented by the abbreviation "spall" followed by the symbol of the target element. High energy fission reactions are similarly represented by the words "spall-fission," and thermal or low energy neutron fission simply by "fission."

The criterion for listing genetic relationships has been with few exceptions that these relationships be demonstrated experimentally; for example, by chemical "milking" of daughter activities, analysis of growth-decay curves, or in the case of short lived isomers, by delayed coincidence experiments. The listing of these parent-daughter relationships gives some warning to the reader as to what he may expect in the way of radiation from a given isotope, since a sufficiently short lived daughter's radiation will usually be observed with that of the parent.

A few further abbreviations are listed below:

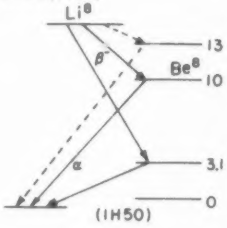
NNES-PPR	Volumes of the National Nuclear Energy Series, Plutonium Project Record, McGraw-Hill Book Co., Inc., New York
[]	Properties listed in brackets have not been observed directly, but have been inferred from other experimental data
est, calc	Estimated or calculated from theoretical or empirical considerations
HPS	Refers to the authors of this compilation
lim	Experimental upper limit
emuls	Photographic emulsion

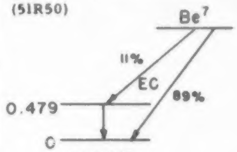
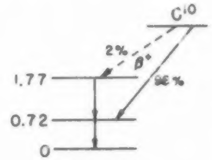
A considerable fraction of the effort necessary to produce this table consisted of abstracting the literature and organizing the data over the past few years. We are greatly indebted to Marjorie Hollander for her efficacious handling of this work, and in addition for her preparation of the drawings.

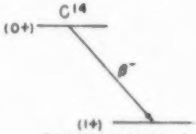
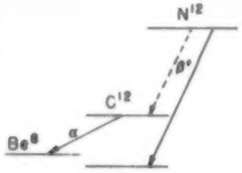
It is a pleasure to acknowledge the generous help and constructive criticism which we have received from our friends and colleagues, and to thank many of the authors whose measurements are cited for their aid in evaluating data familiar to them. We are especially grateful to Dr. Gerhart Friedlander for his invaluable assistance in checking the entire draft.

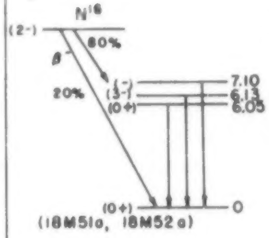
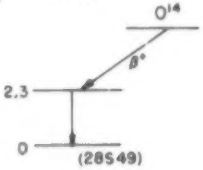
We would also like to express our appreciation to Mildred Davis for the speed and accuracy with which she prepared the manuscript.

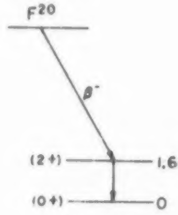
The compilation of this table was supported by the U. S. Atomic Energy Commission.

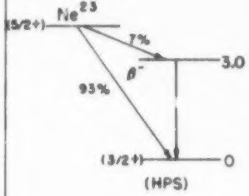
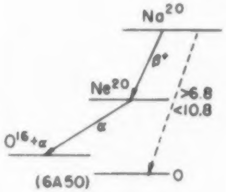
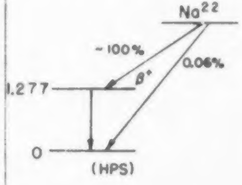
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_0n^1$	A recoil nuclei, conservation of momentum (18C32); observation of n-α reaction (4F32, 87H33)		β^- (18C35, 26S50)	12.8 m (2R51); 10-30 m (26S50)	0.78 p-β^- spect coinc (2R51)		Q_β^- 0.7823 (161.51) n^1, I = 1/2 (87M50)	Be-α-n (18C32); spall reactions in general; fission (92H39, 27A39, 118S39); parent H^1 (26S50, 2R50)
$_1H^1$		99.9849 - 99.9861 (diff sources) (52K51); 99.9851 (1V38)					H^1, I = 1/2 (87M50)	
H^2		0.0139-0.0151 (diff sources) (52K51); 0.0149 (1V38)					H^2, I = 1 (87M50)	
H^3	A chem, sep isotopes, excit (6A39, 6A40a)		β^- (6A39, 6A40a)	12.46 y genet (12J50); 12.4 y sp act (11J51); 12.1 y genet (8N47)	0.01795 spect (10L52b); 0.0183 ion ch (21C49); 0.0194 spect (26H51); 0.0189 ion ch (24H49); 0.0186 (72S49a, calc from 12J49); 0.0180 abs bremsstrahlung Zr, Ta (17G49); others (22B49, 21C48, 35K51b, 5I51)	no γ (18G46)	Q_β^- 0.019 (HPS) H^3, I = 1/2 (87M50)	D-d-p (6A39, 6A40a); D-n-γ (3Z43); He^3-n-p (19C48, 28H48); Li-n-t (4O40); Be-d-t (4O40a, 6A40a); B-n-t, N-n-t (20C41); spall reactions (33B52)
$_2He^3$		1.3×10^{-4} (atmos), 1.7×10^{-5} (wells) (7A46, 19C49)					He^3, I = 1/2 (87M50)	
He^4		~100					He^4, I = 0 (87M50)	
He^6	A chem (23B36, 23B36a); cross bomb, excit, chem (27S46)		β^- (23B36b)	0.823 s (9A50); 0.82 s (27H49); 0.84 s (12R49); 0.85 s (27S46)	3.50 spect (16W52); 3.2 abs (12R49); 3.5 abs (27S46); others (23B36b, 16K48, 2P50, 35A50)	no γ (16K48, 27S46)	Q_β^- 3.50 (16W52); Q_β^- 3.55 (36D52)	Be-n-α (23B36, 9P37, 27S46, 16K48, 2P50); Li-γ-p (25B47, 44S52a)
$_3Li^6$		7.52 (17L38)					Li^6, I = 1 (87M50)	
Li^{7m}	A excit (4E49)		IT (4E49)	5.2×10^{-14} s Doppler broadening (4E49)		~0.48 spect (4E49)		B-n-α (4E49)
Li^7		92.48 (17L38)					Li^7, I = 3/2 (87M50)	
Li^8	A excit (22C35, 11L37); n-capt, sep isotopes, genet (28H47)		β^-, 2α (11L37)	0.825 s (11R51); 0.88 s (26B37, 3O47, 10B49); 0.85 s (44S52a); 0.89 s (28H47)	β^-: 13 (~90%), ~6 (~5%), ~3 (~5%) spect (1H50); <13 (~2%) β-γ coinc abs (5V51a); 12.0 cl ch (26B37); abs (3O47); two α's: total energy 3.2, 7-9 cl ch (27B48)	no γ (13R37, 26B37); γ (very weak) β-γ coinc (5V51a)	Q_β^- 15.99 (9V52)  	Li-n-γ (15K36, 10P46, 28H47); Li^7-n-γ (28H47); Li-d-p (22C35, 5D35, 1F37, 26B37, 11L37, 1H50, 1Y50); spall C, N, Ne, A, Kr, Xe (13W50); Be-γ-p (3O47, 44S52a, 40T52); B-n-α (18L39); B-γ-2p, B-γ-2pn (44S52a)
Li^9	B excit, cross bomb (20G51)		β^-, n (20G51, 78H52)	0.168 s (20G51); 0.170 s (78H52); 0.19 s (44S52a)				Be-d-2p (20G51); B-p-3p, B-d-3pn (20G51); B-γ-2p (44S52a); C-d-4pn, C-p-4p (20G51); C-p-4p (78H52)

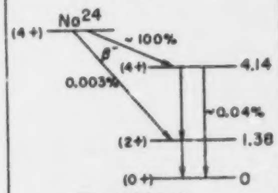
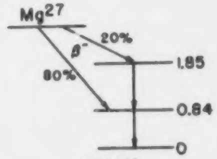
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_4\mathrm{Be}^7$	A chem, cross bomb, excit (13R38)		EC (13R38)	52.93 d (24S49); 53.61 d (58K52); 54.3 d (55B47); 54.5 d (29B49)		0.479 spect (4E48, 11T49); 0.478 spect (1H4'); 0.485 spect (17K48); coinc abs (4Z42); 0.474 spect (5Z48a); γ (11%) (14W49), (10-13%) (10T49) (Be^7 formation yield - γ ratio); others (15R46, 7S47b)	Q_{EC} 0.864 p-n-threshold (51R50)  (14W49)	Li-d-n (13R38, 14R38, 14R38a, 4Z42); Li-p-n (39H39, 39H40); B-p-α (14R38a, 17M39); B-d-αn (12M46); spall C (4D50, 74M51), Al, Cu, Ag, Au (74M51)
Be^8	A observation of Be-γ-n reaction (18C35)		2α	<2 x 10^{-14} s photo-dis O^{16} emuls (26W51); <5 x 10^{-14} s photo-dis O^{16} emuls (18M52); 10^{-15} - 10^{-17} s calc (15W41)	energy of each α in center of mass system: 0.039 spect (41C51); 0.045 spect (12T49); 0.051 ion ch (40H49); 0.043 range emuls (23C50)		Q_α 0.078 (41C51); Q_α 0.089 (12T49); Q_α 0.103 (40H49); Q_α 0.085 (23C50)	Be-p-d (12T49); Be-γ-n (18C35, 40H49); O-γ-2α (18M51, 53L52)
Be^9		100 (6N37)					Be^9, I = 3/2 (100S51, 77H51)	
Be^{10}	A chem (12M46a); chem, mass spect (11P46)		β^- (12M46a)	2.5 x 10^6 y sp act + mass spect (12M47); 2.9 x 10^6 y yield (28H47a)	0.555 spect (15F52); 0.560 spect (13A50); abs (12M46a, 12M47); 0.553 ion ch (11F49a); others (28H49, 16W49, 41H49, 11B50a)	no γ (12M47, 19L47, 28H49)	Q_β^- 0.56 (HPS)	Be-d-p (12M46a, 19L47); Be-n-γ (28H47a, 13A50, 11B50a); B-n-p (9E48); C-n-α (28H46)
$_5\mathrm{B}^8$	A excit, cross bomb (6A50)		β^+, 2α (6A50)	0.46 s (102B52a); 0.61 s (44S52a)	β^+: 13.7 abs (6A50); spect (44S52a)		Q_β^+ 18 (calc from 6A50)	B-γ-2n, B-γ-3n (44S52a); B-p-t (6A50); Be-p-2n (6A50); C-p-nα (6A50); C-γ-p3n (44S52a); spall reactions (33B52)
B^{10}		18.45 - 18.98 (13T48)					B^{10}, I = 3 (87M50)	
B^{11}		81.02 - 81.55 (13T48)					B^{11}, I = 3/2 (87M50)	
B^{12}	A excit (22C35a, 1F36)		β^- (22C35a)	0.027 s delay coinc (3J48a, 30B51); 0.022 s delay coinc (25B39)	13.43 spect (1H50); 13.3 abs (30H48); 12 cl ch (26B37); ~9 (~4%) coinc abs (5V51a)	~4.5 β-γ coinc abs (5V51)		B-d-p (22C35a, 1F36, 30B51); C^{14}-d-α (32H50b); N^{15}-n-α (3J48a)
$_6\mathrm{C}^{10}$	A chem, sep isotopes (28S48, 28S49)		β^+ (28S49)	19.1 s (28S49)	2.2 abs (28S49)	0.72 (~100%), 1.05 (~2%) scint spect (28S52)	 (28S52)	B-p-n, B^{10}-p-n (28S48, 28S49, 28S52); C-γ-2n (44S52a)

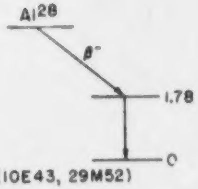
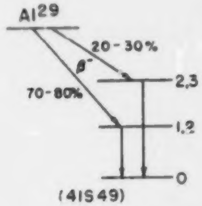
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_6C^{11}$	A excit (22C34, 35H34); chem, excit (33B39)		β^+ (22C34)	20.4 m (30S41); 20.5 m (29S41, 12P48, 25C50); 20.0 m (7S44a, 4D51)	0.99 spect (7S44a); 0.981 spect (14T41); 0.95 cl ch (5D40)	no γ, β-γ coinc (7S46a)	Q_β^+ 2.0 (HPS)	Be-α-2n (12M46b); Be-He^3-n (1P52); B-d-n (26C35, 2Y35, 1F36); B-p-γ (22C34a, 33B39); B-p-n (33B39); C-γ-n (10B46, 12P48, 25C50, 55S51, 22E52, 44S52a); C-n-2n (1P37, 110S51, 30B52); C-d-dn (6T47); C-p-pn (27C47, 82H52); C-He^3-α (1P52); C-α-αn (12M46b, 6T47); N-p-α (33B39); N-n-p3n (16K47); N-γ-p2n (10B46); N-π^--3n (21T51a); O-γ-αn (10B46, 85H52); O-n-α2n (12M47a); O-π^--p4n (21T51a); spall Cu (57G51)
C^{12}		98.892 (limestone CO_2)(6N50)					C^{12}, I = 0 (87M50)	
C^{13}		1.108 (limestone CO_2)(6N50)					C^{13}, I = 1/2 (87M50)	
C^{14}	A chem, cross bomb, excit (16R41)		β^- (1K40)	5568 y weighted average of 3E50, 11J49, 21M50, and 20M51, all by sp act + mass spect (3L51); others (31H49, 17R46, 31H48, 10N48, 1Y48, 17W48)	0.155 spect (15F49, 18W50); 0.156 spect (28C48); 0.154 spect (2L47a), abs (29S47); 0.155 ion ch (10A49); no conv, spect (2L47a); E (average) 0.045 calorimetric (12J52)	no γ (16R41)	Q_β^- 0.155 (HPS) C^{14}, I = 0 (87M50)  (90B52, 90B52a)	C-d-p (16R40, 16R41); C-n-γ (20L45); N-n-p (16R41, 20L45); O-n-α (19M47)
C^{15}	C excit, sep isotopes (32H50)		β^- (32H50)	2.4 s (32H50a)	8.8 abs (32H50a)	5.5 β-γ coinc abs (32H52)		C^{14}-d-p (32H50, 32H50a, 32H52); not found by: C^{14}-n-γ (1Y50)
$_7N^{12}$	A excit, sep isotopes (6A49)		β^+, $\beta^+3\alpha$ (6A50)	0.0125 s delay coinc (6A49)	β^+: 16.6 abs (6A49); α: ~4 total energy of three α's (6A50)		 (6A50)	C-p-n, C^{12}-p-n (6A49, 6A50); N-γ-2n (33P52)

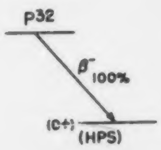
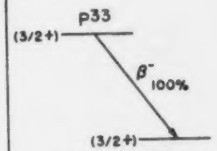
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_7N^{13}$	A excit (4C34, 22C34)		β^+ (22C34)	9.93 m (5W39a); 10.1 m (7S45); 10.2 m (28C48a)	1.24 spect (7S45); 1.25 spect (28C48a); 1.20 spect (1H48); 1.22 spect (14T41); others (21L39, 53K43)	no γ >0.1 [illegible], <0.700 (1[illegible]L47, 7S46a)	Q_β^+ 2.26 (HPS)	B-α-n (4C34, 8E35, 18R37); C-d-n (22C34, 33H35, 2Y35, 26C35, 1F36); C-p-γ (33H35, 26C35); C^{13}-p-n (11A50); N-n-2n (1P37, 34H43); N-d-t (34B42); N-γ-n (10B46, 12P48, 22E52, 44S52a); O-n-p3n (16K47); O-γ-p2n (85H52); spall Al (74M52)
N^{14}		99.635 (6N50)					N^{14}, I = 1 (87M50)	
N^{15}		0.365 (6N50)					N^{15}, I = 1/2 (87M50)	
N^{16}	A excit (22L34, 16F34)		β^- (22L34, 16F34)	7.35 s (35B47); 7.5 s (28H46a); 7.3 s (27S46)	~10.3 (~20%), ~4.3 (~40%), ~3.8 (~40%) cl ch (35B47); 10, 3.5 abs (27S46); 10 cl ch (28H46a)	γ_1 6.13, γ_2 7.10 (γ_2/γ_1 0.08) pair spect (18M51a); 6.2, 6.7 abs sec, cl ch pair (35B46)	Q_β^- 10.3 (35B47)  N16 (2-) β⁻ 80% 20% (-) (3-) (0+) 7.10 6.13 6.05 (0+) 0 (18M51a, 18M52a)	N-n-γ (28H46a, 41F52); N-d-p (1F36); O-n-p (7C37, 26S43, 35B47, 18M51a); F-n-α (22L34, 16F34, 3N36, 2N36, 9P37)
N^{17}	A chem, cross bomb (6A49a, 18K48, 27C48)		β^-, n (18K48)	4.14 s (18K48); 4.15 s (32S51)	β^-: 3.7 β-recoil coinc abs (6A49a); n: 0.9 (mean) O^{16} recoil in ion ch (6A49a); 1.0 (mean) p recoil in cl ch (36H49)		Q_β^- 8.7 (6A49a)	spall O, F, Na, Mg, Al, Si, P, S, Cl, K (27C48, 18K48); C^{14}-α-p (31S51); O-n-p (83C49); O^{18}-γ-p (32S51); F-γ-2p (44S52a)
$_8C^{14}$	B chem, excit (28S49)		β^+ (28S49)	76.5 s (28S49)	1.8 abs (28S49)	2.3 coinc abs sec (28S49)	Q_β^+ 5.1 (28S49)  	N-p-n (28S49); O-γ-2n (44S52a)
O^{15}	A chem, excit (22L34a, 12M35); excit (1F36, 19K39)		β^+ (22L34a)	118.0 s (2P49); 126 s (12M35, 37B39); 127 s (35D51)	1.683 spect (36B50); 1.68 abs (28S49)	no γ (2P50b)	Q_β^+ 2.70 (HPS)	C-α-n (19K39); N-d-n (22L34a, 12M35, 1F36, 36B50); N-p-γ (2D38, 35D51); O-γ-n (37B39, 34H43, 10B46, 12P48, 22E52, 44S52a); O-n-2n (1P37); O-He^3-α (1P52)

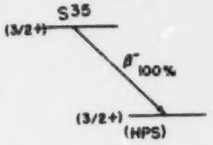
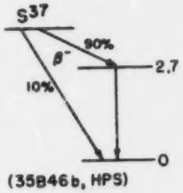
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_8O^{16}$		99.759 (air O_2) (6N50); O^{16}/O^{18} variation ≤ ~4% (13T49, 1K46)					O^{16}, I = 0 (87M50)	
O^{17}		0.037 (air O_2) (6N50)					O^{17}, I = 5/2 (3A51)	
O^{18}		0.204 (air O_2) (6N50)					O^{18}, I = 0 (91M51)	
O^{19}	A excit (3N36); n-capt (22M43)		β^- (22M43)	29.4 s (11F44a); 29.5 s (28H46a); 27.0 s (35B47a)	4.5 (30%), 2.9 (70%) abs (35B47a); 4.1 abs (11F44a); ~3.2 abs (34H45)	1.6 abs (11F44a)		O-n-γ (22M43, 2S46, 2S47); F-n-p (12A35, 3N36)
$_9F^{17}$	A cross bomb (19W34, 8E34a); chem, excit (12N35, 37H35, 2D38)		β^+ (12N35)	70 s (12N35, 2P50c); 60 s (86H52); 66 s (46L51); 72 s (12P48); 74 s (2D38)	1.72 spect (2P50c); 1.7 abs (46L51); 2.1 cl ch (17K36)	no γ (2P51, 51R51)	Q^+_β 2.74 (HPS)	N-α-n (19W34, 8E34a, 18R37); O-d-n (12N35, 1F36, 2P50c); O-p-γ (2D38); F-γ-2n (10B46, 12P48, 86H52)
F^{18}	A chem (26S37); chem, sep isotopes, excit (2D38)		β^+ (26S37)	112 m (26S37, 12P48, 47B49); 115 m (34H43); 107 m (2D38)	0.649 spect (19R51); 0.635 spect (47B49); others (3Y38, 9K41, 20K45, 38H48)	no γ (16K48, 47B49)	Q^+_β 1.67 (19R51)	O-α-pn (2T47a); O^{18}-p-n (2D38); O-d-n (3Y38, 3D40, 20W41); O-He^3-p (1P52); O-t-n (20K45); F-n-2n (1P37); F-d-t (9K41, 34B42); F-γ-n (34H43, 10B46, 12P48, 22E52, 86H52); F-p-pn (19R51); Ne-d-α (26S37); Na-γ-αn (10B46, 85H52); spall Al (74M52, 74M52a), Cu (57G51, 74M52a), Cl, Ag, Au (74M52a)
F^{19}		100 (1A20)					F^{19}, I = 1/2 (87M50)	
F^{20}	A excit (22C35, 1F36, 3N36)		β^- (22C35)	10.7 s (33S50); 12 s (22C35)	5.41, no ~7 β^- (lim 1%) spect (13A52b); 5.33 (97%), 6.7 (3%) spect (47L50); 5.0 spect, abs (3J50); others (38B40)	1.631, no 2.5 γ (lim 0.2%) spect, Be-γ-n reaction (13A52b); 1.64, no 2.5 γ spect, γ-γ coinc (47L50); 1.64, 2.5 (weak) spect, abs sec (3J50); 2.2 cl ch recoil (38B40); γ (coinc with 5.0 β^-) β-γ coinc (21C40, 3J50)	Q^-_β 7.04 (13A52b)  (13A52b)	F-d-p (22C35, 1F36, 33S50, 3J50, 13N50, 13A52c); F-n-γ (3N36, 2S47, 21K50); Na-n-α (3N36)

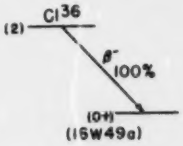
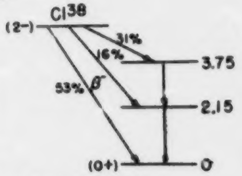
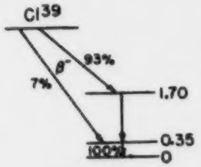
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{10}Ne^{19}$	A cross bomb, excit (21W39)		β^+ (21W39)	18. 2 s (28S49); 18. 5 s (34S52); 20. 3 s (21W39)	2. 8 pect (34S52); 2. 2 cl ch (21W39); 2. 3 abs (28S49)	no γ (21W39, 34S52)	Q_β^+ 3. 20 (HPS)	F-p-n (21W39, 47B51a, 34S52)
Ne^{20}		90. 92 (6N50a)					Ne^{20}, I = 0 (87M50)	
Ne^{21}		0. 257 (6N50a)					Ne^{21}, I = 3/2 (87M50)	
Ne^{22}		8. 82 (6N50a)					Ne^{22}, I = 0 (87M50)	
Ne^{23}	A excit (12A35); chem (23B37, 9P37)		β^- (14F40)	40. 2 s (36B50a); 40. 7 s (34H44a); 40 s (12A35, 23B37)	4. 21 (~93%), 1. 18 (~7%) spect (36B50a); 4. [illegible] abs (35B46a, calc from 14P40); 4. 1 abs (14P40)	~3 abs (2P50a)	Q_β^- 4. 21 (2P50a)  Ne^{23} (5/2+) 7% β^- 93% 3.0 (3/2+) 0 (HPS)	Ne-n-γ (41F52); Ne-d-p (22W40); Ne^{22}-d-p (14F40, 36B50a, 2P50a); Na-n-p (12A35, 3N36, 9P37, 23B37); Mg-n-α (12A35)
$_{11}Na^{20}$	A excit (6A50)		β^+, α (6A50, 44S51a)	0. 385 s (102B52a); 0. 23 s (44S51a)	3. 5 < β^+ < 7. 3 est (44S51a)		 Na^{20} β^+ Ne^{20} >6.8 <10.8 α $O^{16}+\alpha$ (6A50) 0	Ne-p-n (6A50); Na-γ-3n (44S51a, 44S52a)
Na^{21}	A excit (29C40a)		β^+ (14P40)	22. 8 s (34S52); 23 s (29C40a)	2. 50 spect (34S52); 2. 53 spect (52B51b)	no γ (34S52)		Ne^{20}-p-γ (40B47); Ne-p-n (29C40a); Ne-d-n (14P40); Mg-p-α (34S52); Mg^{24}-p-α (39B48)
Na^{22}	A chem, excit (17F35)		β^+ ~100%, no EC (21G46)	2. 60 y (23L49); 2. 8 y (36S39)	0. 542 spect (23M50); 0. 575 spect (21G46); ~1. 8 (0. 06%) spect (56W52); ~1. 8 (0. 004%) cl ch (25M49); others (23L37, 2C39)	1. 277 spect (13A49); 1. 30 (coinc with β^+) spect, β-γ coinc (21G46); 1. 3 spect (2C39) others (85S51)	Q_β^+ 2. 84 (HPS) Na^{22}, I = 3 (87M50)  Na^{22} ~100% β^+ 0.06% 1.277 0 (HPS)	F-α-n (17F35, 23L37, 24M37); Ne-d-n (23L37); Ne^{21}-p-γ (40B47); Na-n-2n (41B46 [illegible]); Mg-d-α (23L3[illegible]); spall Mg, Mg [illegible] (92M51), Fe [illegible]52), Cu (42B51a)
Na^{23}		100 (37S36a)					Na^{23}, I = 3/2 (87M50)	

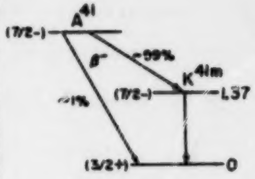
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{11}Na^{24}$	A chem, excit (16F34, 1L35)		β^- (1L35)	15.06 h (39S51); 15.04 h (29S50); 15.10 h (31C50); 15.0 h (38S51, 23W49)	1.390 spect, coinc (7S46b, 7S47); 1.4 spect (24L39); 4.17 (0.003%), no 5.5 β^-, spect (15T51); lim 4.15 β^-, 0.01% spect (22G50); others (42H48)	γ_1 1.3679, γ_2 2.7535 spect (12H52); γ_1 1.380, γ_2 2.758 spect (7S46b); 1.380, 2.765 spect (20R49); γ_2 (e/γ 3×10^{-6}) (7S50b); 2.748 spect (21K50a); 2.755 spect (6W50); γ_1 (coinc with γ_2) spect, β-γ, γ-γ coinc (4E43); γ-γ coinc abs (28C46); 3.7 (0.04%) D-γ-p ion ch (101B51); ~4 (0.05%) spect (15T51); others (9B50, 4I41, 26M43, 41M50, 85B50a, 85S51, 55C50, 108B52)	Q_β^- 5.53 (HPS) Na^{24}, I = 4 (101S51)  No^{24} (4+) ~100% β^- (4+) 4.14 0.003% ~0.04% (2+) 1.38 (0+) 0 (HPS, 108B52)	Na-d-p (1L35, 2V36a); Na-n-γ (12A35, 2S47); Mg-d-α (35H35); Mg-n-p (12A35); Mg-γ-p (10B46, 42H47, 22E52); Al-n-α (12A35, 74M52); Al-d-pα (30C46, 30C47); Al-γ-n2p (10B46, 22E52, 42S52); Al-p-3pn (82H52); Si-γ-n3p (?) (10B46); spall Al (39F52), Fe (45R52), Cu (42B51a, 57G51), Sn (42B51); spall-fission Cu (42B51), U (6F51)
Na^{25}	B excit (34H43a)		β^- (34H43a)	58 s (35B47a); 62 s (12P48, 10B46, 34H43a); 60 s (21R44)	3.7 (~55%), 2.7 (~45%) abs (35B47a); 3.4 abs (34H44a); 3.3 abs (21R44)	>0.5 (weak) abs (35B47a)	Q_β^- 3.7 (35B47a)	Mg-γ-p (34H44a, 10B46, 22E52); Mg-n-p (34H44a, 35B47a); Al-γ-2p (10B46, 12P48, 22E52, 42S52)
$_{12}Mg^{23}$	A excit, cross bomb (21W39)		β^+ (21W39)	11.9 s (34H43); 12.3 s (52B51a); 11.6 s (21W39)	2.99 scint spect (52B51a); 2.8 cl ch (21W39)	no γ (21W39)		Na-p-n (21W39, 2D40); Mg-γ-n (34H42, 34H43, 10B46, 25B47, 27M49, 22E52)
Mg^{24}		78.60 (24W48)					Mg^{24}, I = 0 (87M50)	
Mg^{25}		10.11 (24W48)					Mg^{25}, I = 5/2 (87M50, 3A51a)	
Mg^{26}		11.29 (24W48)					Mg^{26}, I = 0 (87M50)	
Mg^{27}	A chem, excit (12A35, 35H35)		β^- (35H35)	9.45 m (3S52); 9.6 m (10E43); 10.0 m (32C39); 10.2 m (35H35)	1.80 (80%), 0.9 (20%) spect (43B48); 1.8 cl ch (10E43, 32C39); 1.7 abs (28M40); ~1.8 (coinc with γ) β-γ coinc (35B47a)	γ_1 1.01, γ_2 0.84 (γ_1 coinc with γ_2) spect, γ-γ coinc (43B48); 1.02, 0.84, 0.64 spect (4I41); 1.05 cl ch recoil (10E43)	Q_β^- 2.64 (43B48)  (43B48)	Mg-d-p (35H35); Mg-n-γ (12A35, 2S47); Al-n-p (12A35, 16F34, 74M52)
Mg^{28}	A chem, genet (37L53)		β^- (37L53)	21.2 h (37L53)	0.3-0.4 abs (37L53)	<0.1 abs (37L53)		spall Cl, parent Al^{28} (37L53)
$_{13}Al^{24}$	A excit, decay charac (102B52)		β^+ or EC, α (p?) (102B52a)	2.3 s (102B52)				Mg-p-n (102B52)
Al^{25}	B excit, sep isotopes (39B48)		β^+ (39B48)	7.3 s (39B48)				Mg^{25}-p-n (39B48)

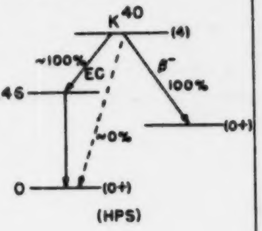
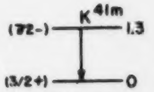
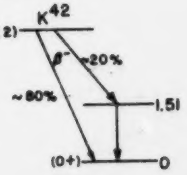
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{13}$Al^{26}	A excit (17F34): cross bomb (34H43, 39B48)		β^+ (17F34)	6. 5 s (30K51); 6. 3 s (39B48); 7. 0 s (21W39, 14A48, 12P48); 7. 2 s (25W48)	2. 8 abs (14A48); 3. 0 cl ch (21W39); 3. 4 abs (35B46a, calc from 17F34)			Na-α-n (17F34, 24M37); Mg-[illegible]-n (21W39); Mg^{26}-p-n (39B48); Mg-p-γ (21C39, 16T46); Al-γ-n (34H41, 34H42, 34H43, 10B46, 25B47, 12P48, 22E52)
Al^{27}		100 (1B50)					Al^{27}, I = 5/2 (87M50)	
Al^{28}	A chem, excit (4C34a, 4C34b, 16F34); chem, cross bomb (12A35)		β^- (12M35a)	2. 27 m (106B52b); 2. 07 m (40S48); 2. 30 m (10E43)	2. 865 spect (29M52); 2. 75 (coinc with γ) coinc abs (35B47a); 3. 01 spect (43B48); no 4. 6 β^- (29M51)	1. 782 spect (29M52); 1. 80 spect (43B48); 1. 80 abs sec (35B47a); 1. 82 spect (4I41)	Q_β^- 4. 65 (29M52)  (10E43, 29M52)	Mg-α-p (8E36, 18R37); Al-d-p (12M35a, 29M52); Al-n-γ (12A35, 2S47, 9O49, 50H51, 29M52); Si-n-p (12A35, 35B47a); Si-γ-p (10B46, 42H47); P-n-α (12A35) daughter Mg^{28} (37L53)
Al^{29}	A excit, cross bomb (32B39)		β^- (32B39)	6. 56 m (41S49); 6. 7 m (32B39)	2. 5 (~70%), 1. 4 (~30%) (both coinc with γ) β-γ coinc abs (41S49); ~2. 5 cl ch, abs (32B39)	1. 2 (~80%) (coinc with 2. 5 β^-), 2. 3 (~20%) coinc abs sec (41S49)	Q_β^- 3. 8 (41S49)  (41S49)	Mg-α-p (8E36, 32B39, 14H39, 41S49); Al-α-2p (112S51); Si-n-p (21F43); Si-γ-p (10B46, 42H47, 12P48); P-γ-2p (10B46, 12P48)
$_{14}$Si^{27}	A excit (22K39)		β^+ (30M40)	4. 9 s (12E41, 29C40a); 4. 5 s (25W48); 5. 4 s (52B51a)	3. 48 scint spect (52B51a); 3. 5 cl ch (33B40); 3. 7 cl ch (30M40)			Mg-α-n (12E41); Al-p-n (22K39, 30M40, 29C40a, 33B40, 76C51); Si-γ-n (34H44, 25B47, 25W48)
Si^{28}		92. 27 (1B50)					Si^{28}, I = 0 (87M50)	
Si^{29}		4. 68 (1B50)					Si^{29}, I = 1/2 (87M50)	
Si^{30}		3. 05 (1B50)					Si^{30}, I = 0 (87M50)	
Si^{31}	A n-capt (12A35); chem, excit (12N35a)		β^- (12N35a)	2. 62 h (33C38, 55W51); 2. 65 h (29M52a); 2. 6 h (48L50); 2. 8 h (12N37, 15A40) 2. 7 h (15P49)	1. 471 spect (29M52a); 1. 486 spect (47W52); 1. 48 abs (55W51)	0. 17, 0. 52, ~1 (weak) (?) abs (80C52); no γ (12N37)	Q_β^- 1. 47 (29M52a)	Si-d-p (12N35a, 12N37, 17K36); Si-n-γ (12A35, 2S47); Si-He^3-2p (1P52); P-n-p (12A35, 1P37); S-n-α (42S36, 33C38); spall Fe (45R52)

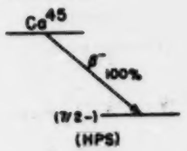
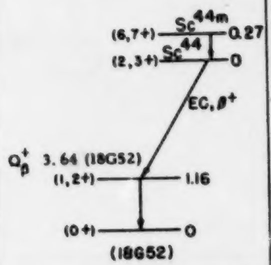
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{15}P^{29}$	B excit (21W41)		β^+ (21W41)	4.57 s (30R52); 4.6 s (21W41)	3.6 cl ch (21W41)	1.28 (2.5%), 2.42 (0.5%), scint spect, γ-γ coinc (30R52)		Si-p-n (21W41); Si-d-n (14D48); P-γ-2n (?) (10B46)
P^{30}	A excit (4C34, 17F34)		β^+ (4C34)	2.55 m (18R37); 2.18 m(33C38)	3.5 spect (24M41); 3.4 abs (35B46a, calc from 17F34); 3.0 cl ch (33B40)			Al-α-n (17F34, 4C34, 18R37); Si-p-n (33B39, 33B40); Si-He^3-p (6A39, 1P52); P-n-2n (1P37); P-γ-n (37B39, 10B46, 12P48); S-d-α (42S36); Cl-γ-αn (85H52)
P^{31}		100 (1A20)					P^{31}, I = 1/2 (87M50)	
P^{32}	A chem, n-capt (12A35)		β^- (21L37)	14.30 d (12C38, 45B50); 14.35 d (23K48); 14.07 d (31M40); 14.60 d (38S51)	1.701 spect (average of 44S51, 29M52a, 13J52b, 8H51b, 16A50, 18W50a, 10L49, 7S46b); E (average) 0.70 ion ch (77C52)	no γ (17K36, 7S46b)	Q_β^- 1.702 (HPS) 	Si-d-γ (112S51); Si-α-p (18F35); Si-He^3-p (1P52); P-d-p (12N37); P-n-γ (2S47); S-n-p (12A35); S-d-α (42S36); Cl-n-α (12A35); Cl-γ-αn, Cl-γ-t (85H52); Cl-d-pα (17T47); spall Fe (45R52), Cu (32M48, 42B51a)
P^{33}	A chem, cross bomb (44S51)		β^- (13J52b, 44S51)	25.4 d (58W52); 24.8 d (13J52b); 25 d (44S51)	0.27 spect (44S51); 0.26 spect (13J52b); 0.25 abs (58W52)	no γ (44S51, 58W52)	Q_β^- 0.27 (44S51)  (44S51, 13J52b)	S-n-p (44S51, 13J52b, 58W52); S-γ-p (44S51, 13J52b); Cl-γ-α, Cl. γ-2p (44S51, 13J52b)
P^{34}	B excit (10C40a); chem, excit, cross bomb (35B46b)		β^- (6Z45)	12.4 s (35B46b); 12.7 s (10C40a)	5.1 (75%), 3.2 (25%) abs (35B46b)			S-n-p (10C40a, 6Z45, 35B46b); Cl-n-α (6Z45, 34H45, 35B46b)
$_{16}S^{31}$	A excit, cross bomb (21W41, 12E41)		β^+ (21W41)	3.18 s (12E41); 3.2 s (21W41, 52B51a); 2.6 s (27M49)	3.85 cl ch (21W41); 3.87 cl ch (12E41a); 4.1 scint spect (52B51a)			Si-α-n (19K40, 12E41, 12E41a); P-p-n (21W41); S-γ-n (34H41, 34H42, 34H43, 25B47, 27M49)
S^{32}		95.018 (meteoritic sulfur) (76M50a); terrestrial S^{32}/S^{34} variation <5% (41T50)					S^{32}, I = 0 (87M50)	

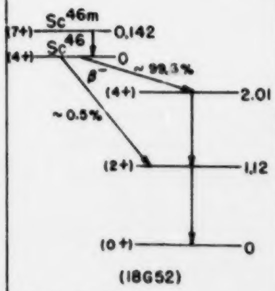
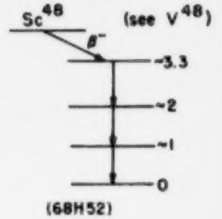
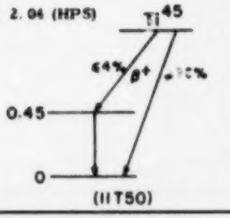
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{16}S^{33}$		0.750 (meteoritic sulfur) (76M50a)					S^{33}, I = 3/2 (87M50)	
S^{34}		4.215 (meteoritic sulfur) (76M50a)					S^{34}, I = 0 (87M50)	
S^{35}	A chem, excit (17A36); chem, cross bomb, excit (1K41); sep isotopes (1K42)		β^- (3L39)	87.1 d (44H43) 88 d (26L40, 1K41)	0.1670 spect (10L50c); 0.167 spect (45H51), abs (29S47); 0.169 spect (46B48), abs (1Y48a); 0.168 spect (23G50); 0.166 spect (18A48); 0.168 ion ch (56C49)		Q_β^- 0.167 (HPS) S^{35}, I = 3/2 (87M50) 	S-n-γ (2S47); S-d-p (34C39, 1K41); Cl-n-p (17A36, 26L40, 1K41, 3M49); Cl^{35}-n-p (1K42); Cl-d-α (1K41); spall *Fe* (45R52)
S^{36}		0.017 (meteoritic sulfur) (76M50a)					S^{36}, I = 0 (87M50)	
S^{37}	B chem, excit cross bomb (6Z45, 35B46b)		β^- (6Z45)	5.04 m (35B46b); 5.0 m (28H46b)	4.3 (10%), 1.6 (90%) abs (6Z45, 35B46b); 1.4, ~4 abs (28H46b)	2.7 abs sec (35B46b); 2.75 abs sec (28H46b)	Q_β^- 4.3 (HPS) 	S-n-γ (28H46b); Cl-n-p (6Z45, 35B46b)
$_{17}Cl^{33}$	A excit (46H40); excit (21W41)		β^+ (21W41)	2.8 s (46H40, 45S48); 2.4 s (21W41); 1.8 s (52B51a)	4.13 cl ch (21W41); 4.4 scint spect (52B51a)			S-d-n (46H40, 45S48); S-p-n (21W41); Cl-γ-2n (52B51a)
Cl^{34}	A chem, excit (17F34); chem, excit (42S36)		β^+ (17F34, 44B38)	33.2 m (25W48); 33.0 m (12P48); 33 m (42S36, 44B38)	4.5 (46%), 2.6 (28%), 1.3 (26%) spect (19R51); 5.1 (~80%), 2.4 (~20%) cl ch (38H46)	3.22, 2.10, 1.16 scint spect (18T51); 3.3, 2.1, 0.145 spect, spect conv (19R51); 3.4 cl ch recoil (38H46)	Q_β^+ 5.6 (19R51)	Al-C^{12}-αn (4M50); P-α-n (17F34, 18R37, 44B38); S-d-n (42S36, 38H46); S-α, pn (28S40); S-p n (19R51); S-t-n (20K45); Cl-n-2n (1P37); Cl-p-pn (19R51); Cl-γ-n (37B39, 34H43, 12P48, 25W48, 22E52); spall Fe (45R52), Cu (42B51a)
Cl^{35}		75.4 (6N36)					Cl^{35}, I = 3/2 (87M50)	

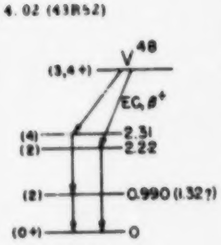
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{17}\mathrm{Cl}^{36}$	A chem, n-capt (31G41)		β^- (31G41); no β^+ (lim 0.01%) (16W49a); (lim 0.03%) (14J49)	4.4 x 10^5 y sp act (16W49a); 3.6 x 10^5 y sp act (22R49); 2.0 x 10^5 y yield (22R49); 2 x 10^6 y yield (28H47b); -10^6 y yield (10C47)	0.714 spect (15F52); 0.66 abs (10O47); 0.64 abs (31G41); others (16W49b, 16W51)	no γ (16W49a)	Q_β^- 0.714 (16W49b, 15F52) Cl^{36}, I = 2 (87M50, 27J51)  (16W49a)	Cl-n-γ (31G41, 10O47, 2S47); Cl-d-p (31G41)
Cl^{37}		24.6 (6N36)					Cl^{37}, I = 3/2 (87M50)	
Cl^{38}	A chem, n-capt (12A35); chem, sep isotopes (14K43)		β^- (17K36)	37.29 m (31C50); 37.5 m (47H37, 21C40a); 37.0 m (2V36a, 5S45); 38.5 m (15H46)	4.81 (53%), 2.77 (16%), 1.11 (31%) spect (10L50); 5.0, 2.8, 1.1 spect (27W39); spect, coinc abs (27W41); 5.2 (53%), 2.70 (11%), 1.19 (36%) spect (15H46)	γ_1 2.15, γ_2 1.60 (γ_1/γ_2 = 1.3) spect (15H46); γ_1 2.19, γ_2 1.64 (γ_1 coinc with γ_2) spect, coinc (4I41); 2.15, 1.65 spect (21C40a); no 3.75 γ (lim 0.03%) Be-γ-n reaction (33M49)	Q_β^- 4.81 (HPS)  Cl38 (2−) 31% 16% 53% β- 3.75 2.15 (0+) 0 (10L50, 15H46)	Cl-d-p (17K36, 2V36a); Cl-n-γ (12A35, 14K40, 19A41, 2S47); Cl^{37}-n-γ (14K40); K-n-α (47H37); spall Fe (45R52), Co (29W52), Cu (32M48, 42B51a); spall-fission Cu (42B51)
Cl^{39}	A chem (32M48a); chem, excit (49H49)		β^- (49H49)	55.5 m (49H49); -1 h (32M48a, 48H49)	1.65 (93%), 2.96 (7%) abs (49H50)	1.35, 0.35 (coinc with 1.65 β^-) coinc abs sec (49H50)	Q_β^- 3.3 (49H50)  (49H50)	A-γ-p (49H49, 49H50); spall Fe (45R52), Co (29W52), Cu (32M48a, 42B51a), As (48H49)
$_{18}\mathrm{A}^{35}$	A excit (21W41, 19K40)		β^+ (12E41a, 21W41)	1.88 s (12E41a); 1.84 s (45S48)	4.38 cl ch (21W41); 4.41 cl ch (12E41a)		Q_β^+ 5.4 (HPS)	S-α-n (19K40, 45S48); Cl-p-n (21W41)
A^{36}		0.337 (6N50)					A^{36}, I = 0 (87M50)	
A^{37}	A chem, cross bomb (28W41)		EC (28W44, 46R52); EC (L/K 0.087) (17P49)	35.0 d (56M52); 34.1 d (28W44)		no γ, Cl K_α-x (28W44)	Q_{EC} -0.8 continuous γ spectrum (38A52); Q_{EC} 0.816 p-n threshold (51R50)	S-α-n (28W41, 28W44); Cl-d-2n (28W41, 28W44); Cl-p-n (28W41, 28W44, 47B51a); K-d-α (28W41, 28W44); Ca-n-α (28W41, 28W44)
A^{38}		0.063 (6N50)						
A^{39}	B chem, excit (8Z52)		β^- (48B50)	-265 y sp act (8Z52)	0.565 spect (48B50)	no γ > 0.3 (lim 0.1%) (48B50)	Q_β^- 0.57 (HPS)	A-n-γ (32K52); K-n-p (48B50, 8Z52)

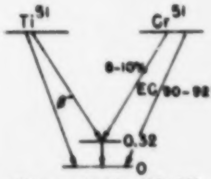
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{18}A^{40}$		99. 600 (6N50)					A^{40}, I = 0 (87M50)	
A^{41}	A chem, excit (26S36)		β^- (26S36)	109 m (35B46c); 110 m (26S36)	1. 245 (~100%) spect (36B50); 1. 18 (99. 3%), 2. 5 (0. 7%) abs, coinc abs (35B46c); others (26S36, 17K36)	1. 37 cl ch recoil (23R36); 1. 3 (coinc with 1. 2 β^-) β-γ coinc, abs sec (35B46c); γ (e/γ ~0) spect conv (36B49)	Q_β^- 2. 5 (35B46c)  (35B46c, 4E52)	A-d-p (26S36, 36B49, 36B50); A-n-γ (26S36); K-n-p (47H37, 35B46c); parent K^{41m} (4E52)
A^{42}	A chem, genet (32K52)		β^- (32K52)	≥3. 5 y (32K52)				A-n-γ (sec order reaction) (32K52); parent K^{42} (32K52)
$_{19}K^{37}$	C excit (27L48)		β^+ (52B51a)	1. 3 s (27L48); 1. 2 s (52B51a)	4. 6 scint spect (52B51a)			K-γ-2n (27L48, 52B51a)
K^{38}	A chem, cross bomb (47H37, 14H37)		β^+ (47H37)	7. 7 m (47H37, 18R37, 58G51); 7. 5 m (24R47); 7. 6 m (12P48)	2. 8 spect (58G51); 2. 5 abs (24R47); others (18R37)	2. 16 scint spect (18T51); ~2. 1 abs sec (24R47)	see Cl^{38}	Cl-a-n (47H37, 18R37, 14H37, 24R47); K-n-2n (1P37); K-p-pn (18T51, 58G51); K-γ-n (34H42, 34H43, 12P48, 22E52); Ca-d-a (47H37)
K^{39}		93. 08 (6N50); K^{39}/K^{41} variations (81C42)					K^{39}, I = 3/2 (87M50)	

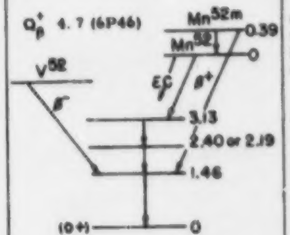
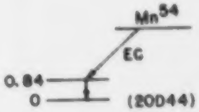
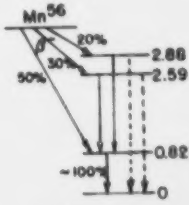
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{19}K^{40}$	A chem (1T05, 54C06); chem, mass spect (15S37)	0.0119 (6N50)	β^- 89%, EC 11% (3150); β^- ~88%, EC (K) ~12% (46S50); β^- ~93%, EC (K) ~7% (36C50); assuming EC/γ = 1, β^- 90%, EC 10% (19F50, 76H50); β^- 91%, EC 9% (48S50); β^- 89%, EC 11% (27G51); β^- 94%, EC 6% (65M52); no β^+ (lim 0.06%) (37C51); no β^+ (lim 0.002%) (11B50b); β^+ ≤0.1% (25G51b)	t_{β^-} sp act (uncorr. for EC): 1.32 x 10^9 y (47S49, 48S50); 1.26 x 10^9 y (17D51, 17D51ab); 1.29 x 10^9 y (19F50); 1.49 x 10^9 y (27G50, 76H50, 25G51); 1.42 x 10^9 y (46S50); others (20A48, 20F49, 111S50); $t_{1/2}$ 1.2 x 10^9 y calc from average t_{β^-} and EC/β^- (HPS)	1.33 spect (15F52); 1.36 spect (13A50a); 1.36 scint spect (11B50c); 1.35 spect coinc (16D46); 1.41 abs (42H46, 42H48); 1.28 scint spect (25G51)	1.46 scint spect (11B50b, 25G51a); 1.48 scint spect (55H50); 1.47 scint spect (18P50); 1.54 (with EC) abs, coinc (42H46); 1.55 abs (26G47); γ (with EC) (34M47, 16P52); γ/β^- 0.12 sp act (average of 19F50, 47S49, 48S50, 25G51, 20F49, 27G48, 46S49, 76H50); EC/γ ~1 (35M51, 46S50, 16P52)	Q_{β}^- 1.33 (HPS) Q_{EC} 1.63 (26R50, HPS) K^{40}, I = 4 (87M50)  K40 (4) ~100% EC β⁻ 100% 1.46 ~0% (0+) 0 (0+) (HPS)	natural source (1T05, 54C06)
K^{41m}	A genet (4E52)		IT (4E52)	6.7 x 10^{-9} s delay coinc (4E52)		~1.3 scint spect (4E52)	 (4E52, 18G52)	daughter A^{41} (4E52)
K^{41}		6.91 (6N50)					K^{41}, I = 3/2 (87M50)	
K^{42}	A chem, n-capt (12A35); chem, cross bomb (71H35, 71H36)		β^- (17K36)	12.44 h (7S47c); 12.5 h (38S51, 35L52a); 12.4 h (47H37)	3.58 (75%), 2.04 (25%) spect (7S47c); 3.60, 1.9 spect (6P47); 3.5 (~70%) (not coinc with γ), ~1.8 (~30%) abs, coinc (35B47a)	1.51 spect (7S47c); 1.50 spect (6P47); 1.5 (17%) scint spect (35L52a)	Q_{β}^- 3.6 (HPS)  (HPS)	A-α-pn (11O49); K-d-p (47H37); K-n-γ (12A35, 47H37, 2S47); Ca-n-p (71H35, 47H37); Sc-n-α (71H36, 47H37, 35B47a); spall Co (29W52), Cu (57G51); daughter A^{42} (32K52)
K^{43}	B chem, excit (11O49)		β^- (11O49)	22.4 h (11O49)	0.81, 0.24 spect, abs (11O49)	~0.4 abs (11C49)		A-α-p (11C49)
K^{44}	E chem, excit (30W37)		β^- (30W37)	18 m (30W37)				Ca-n-p (30W37, 30W40)
$_{20}Ca^{39}$	B excit (34H43, 27M49)		β^+ (34H43)	1.06 s (34H43) 1.1 s (52B51a)	5.1 scint spect (52B51a)			Ca-γ-n (34H43, 25W48, 27M49)
Ca^{40}		96.97 (6N38a)					Ca^{40}, I = 0 (87M50)	

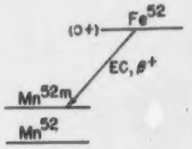
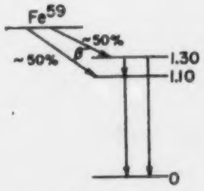
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{20}Ca^{41}$	B chem, n-capt sep isotopes (60B51)		EC (60B51)	1.1×10^{5} y yield (60B52a)		K K_{a}-x (60B51)		Ca-n-γ (49S51, 60B51)
Ca^{42}		0.64 (6N38a)						
Ca^{43}		0.145 (6N38a)						
Ca^{44}		2.06 (6N38a)						
Ca^{45}	A chem, excit, cross bomb (30W40)		β^- (30W40)	152 d (36M47); 180 d (30W40)	0.254 spect (23M50a); 0.255 scint spect (24K50); 0.260 abs (29S48); 0.26 abs (50S50); E (average) 0.075 ion ch (77C52)	no γ (29B48, 37M49, 25K46); others (52M51)	Q_{β}^{-} 0.254 (HPS)  	Ca-d-p (30W40); Ca-n-γ (30W40, 2S47); Sc-n-p (30W40, 25K46); Sc-d-2p (51H48); Ti-n-a (38C48, 63H48); spall Fe (45R52), Cu (42B51a); spall-fission Bi (11G49)
Ca^{46}		0.0033 (6N38a)						
Ca^{47}	A (36M47); chem, genet (42B51a)		β^- (36M47)	4.8 d (42B51a); 5.8 d (36M47)	1.2 abs (42B51a); 1.1 abs (36M47)	1.3 abs (36M47)		Ca-d-p (36M47); spall Fe (45R52), Cu (42B51a); parent Sc^{47} (42B51a)
Ca^{48}		0.185 (6N38a)		$t_{\beta^-} > 2 \times 10^{16}$ y sp act (28J52)				
Ca^{49}	A chem, n-capt, sep isotopes (38M50)		β^- (38M50)	8.5 m (38M50)	-2.7 abs (38M50)	hard (38M50)		Ca^{48}-n-γ, Ca-p-γ (38M50)
$_{21}Sc^{41}$	A excit (12E41)		β^+ (12E41a)	0.873 s (98M52); 0.87 s (12E41)	4.94 cl ch (12E41)			Ca-d-n (12E41, 12E41a); Ca-p-γ (39T52)
Sc^{43}	A chem, excit (17F35)		β^+ (17F35)	3.92 h (53H45); 4 h (30W40a)	1.18 (72%), 0.77 (28%) spect (93H52); 1.12 abs, spect (53H45); 1.4 cl ch (30W37a); abs (30W40a)	0.375, no higher γ (lim 15%) spect (93H52); 1.65 abs (53H45); 1.0 abs (30W40a)		Ca-a-p (17F35, 30W40a); Ca-d-n (30W37a, 53H45); Ca-p-n (2D38, 53H45); spall Fe (45R52), Co (29W52), Cu (42B51a)
Sc^{44m}	A chem, excit cross bomb (30W37a)		IT (30W40a)	2.44 d (53H45); 2.4 d (49B50); 2.2 d (30W40a)		0.271 spect, spect conv (49B50); 0.269 spect conv (51S42); 0.26 spect conv (2H41); 0.28 abs conv (53H45)	 (6,7+) Sc44m 0.27 (2,3+) Sc44 0 EC, β⁺ (1,2+) 1.16 (0+) 0 (18G52)	K^{41}-a-n (49B50); K-a-n (30W40a, 53H43); Ca-d-n (30W37a, 51S42, 53H43); Ca-p-n (2D38); Sc-n-2n (31B38, 53H45); Ti-d-a (30W37b); spall Fe (45R52), Co (29W52), Cu (42B51a)
Sc^{44}	A chem, excit (10C38)		β^+, EC (53H45)	3.92 h (53H45); 4.0 h (49B50); 4.1 h (30W40a, 51S42)	1.463 spect (49B50); 1.45 spect (51S42); 1.5 abs (39C50, 30W40a)	1.16 spect spect conv (49B50); 1.18 coinc abs sec (39C50)	Q_{β}^{+} 3.64 (18G52)	K^{41}-a-n (49B50); K-a-n (30W40a, 53H43); Ca-d-n (30W37a, 51S42, 53H43); Ca-p-n (2D38); Sc-n-2n (31B38, 53H43); Sc-γ-n (37B39); Ti-d-a (53H44); spall Co (29W52), Cu (42B51a); spall-fission Br (42B51)

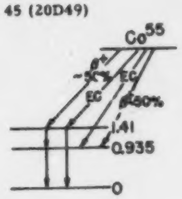
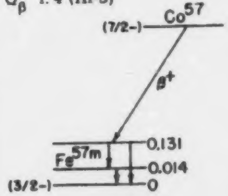
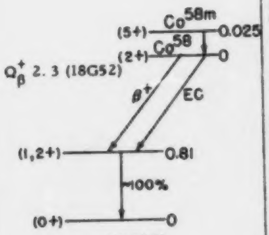
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{21}\text{Sc}^{45}$		100 (28L50)					Sc^{45}, I = 7/2 (87M50)	
Sc^{46m}	A n-capt, resonance neutron activation (18G48)		IT (18G48)	19. 5 s (38M51)		0. 142 (K/L ~10) spect conv (82B52); 0. 135 scint spect (38M51)	 Sc46m Sc46 (7+) (4+) 0,142 0 β⁻ ~ 99,3% ~ 0.5% (4+) 2.01 (2+) 1,12 (0+) 0 (18G52) Q_{β}^{-} 2. 37 (18G52)	Sc-n-γ (18G48, 38M51)
Sc^{46}	A n-capt, chem (71H36); chem, excit, cross bomb (30W37c)		β⁻, no EC (40M47); β⁻, EC (weak) (30W39); no β⁺ (lim 0. 0016%) (41M51)	85 d (30W39); 84 d (19P51)	0. 36 spect (22F47, 40M47, 20P48); 0. 36 abs (52S50); 0. 34 abs (14N50); 1. 2 (~0. 5%) spect (19P51); no 1. 5 β⁻ (lim 0. 05%) cl ch (52S50); no 1. 5 β⁻ (lim 0. 06%) spect (39M50); 1. 5 (~2%) spect (20P48); abs (14N50)	γ_1 0. 89, γ_2 1. 12 spect, spect conv (20P48); 0. 88, 1. 12 spect (22F47); 0. 90, 1. 12 spect (40M47); γ_1 (e/γ 1. 7 x 10^{-4}), γ_2 (e/γ 0. 98 x 10^{-4}) spect conv (39M50); γ_1 (e/γ 1. 4 x 10^{-4}), γ_2 (e/γ 0. 61 x 10^{-4}) spect conv (19P51a); γ_1 (coinc with 0. 36 β⁻ and γ_2) β-γ, γ-γ coinc (15J48, 52S50, 26M48); γ_1 (coinc with 1. 5 β⁻ and γ_2) delay coinc (14N50)		Ca-α-p (30W40a); Sc-d-p (30W37c, 30W39) Sc-n-γ (71H36, 30W37c, 2S47); Ti-d-α (30W37b); Ti-n-p (30W37b, 63H48); spall Fe (45R52), Cu (42B51a)
Sc^{47}	A chem, cross bomb (53H45a); sep isotopes (26K49)		β⁻ (53H45a)	3. 43 d (26K49)	0. 61 abs (26K49)	γ (26K49)		Ca-α-p (53H45a); Ca-d-n (53H45a); Ca-p-γ (53H45a); Ti-γ-p (22E52); Ti-n-p (63H48); Ti^{49}-d-α (26K49); spall Fe (45R52), Cu (42B51a); daughter Ca^{47} (42B51a)
Sc^{48}	A chem, excit (30W37b); sep isotopes (26K49)		β⁻ (30W37b)	44 h (30W40a, 26M42, 53H45a, 26K49)	0. 64 spect (51S42); 0. 57 abs (53H45a, 26K49)	γ_1 1. 33, γ_2 0. 98, γ_3 ~1. 0 scint spect, γ-γ coinc (68H52); 1. 32, 0. 99, no 2. 3 γ (lim 0. 1%) scint spect (69M52); 1. 33, 0. 98 spect (6P46); 1. 35 spect (26M42, 26M43a); 1. 33 abs (53H45a)	Q_{β}^{-} 3. 87 (74S51a)  (68H52)	Ca-p-n (53H43); Ca-d-2n (51S42, 26M42, 53H43, 26M43a); Ti-n-p (30W37b, 1P37, 30W40a, 26M43a); Ti^{50}-d-α (26K49); Ti-d-α (53H44); V-n-α (30W37b, 1P37, 30W40a); spall Fe (45R52)
Sc^{49}	B chem, excit, cross bomb (30W40a)		β⁻ (30W40a)	57 m (30W40a)	1. 8 abs (30W40a)	no γ (30W40a)		Ca-d-n (30W40a); Ti-n-p (30W40a); Ti-γ-p (42H47, 22E52)
$_{22}\text{Ti}^{43}$	E excit (45S48)			0. 6 s (45S48)				Ca-α-n (45S48)
Ti^{45}	A chem, cross bomb, excit (21A41)		β⁺, EC (27K50)	3. 09 h (27K50); 3. 05 h (11T50); 3. 08 h (21A41)	1. 02 (≥96%), 0. 57 (64%) spect (11T50); 1. 00 spect (27K50); 1. 2 cl ch (21A41)	0. 45 (weak), (no 0. 8 γ) spect (11T50); 0. 80 spect, abs (27K50)	Q_{β}^{+} 2. 04 (HPS)  (11T50)	Ca-α-n (21A41); Sc-p-n (21A41, 11T50, 27K50); Sc-d-2n (21A41, 11T50); Ti-n-2n (21A41); Ti-γ-n (34H43b, 34H44, 25W48, 22E52); spall Fe (45R52), Cu (42B51a, 74M52)

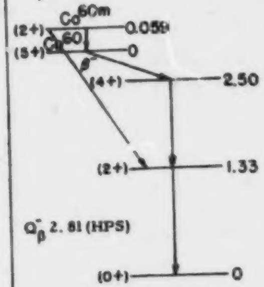
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev Particles	Energy of radiation in Mev Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{22}Ti^{46}$		7.95 (6N38a)						
Ti^{47}		7.75 (6N38a)						
Ti^{48}		73.45 (6N38a)						
Ti^{49}		5.51 (6N38a)					Ti^{49}, I = 7/2 (?) (29J52)	
Ti^{50}		5.34 (6N38a)						
Ti^{51}	B n-capt (2S47)		β^- (2S47)	5.82 m (3S52); 5.75 m (2B52); 6 m (24S49a, 38M50, 2S47)	1.7, 1.35 (coinc with 0.32 γ) scint spect (38M52); 2.2 (~30%), 1.9 (~70%) abs, spect (60K52); 1.6 abs (24S49a)	0.320, 0.910 (weak) scint spect (2B52); 0.32 scint spect (38M51a, 60K52)	see Cr^{51}	Ti-n-γ (2S47, 38M50)
$_{23}V^{46}$	E excit (98M52)		β^+ (98M52)	0.40 s (98M52)	>6.0 scint spect (98M52)			Ti-p-n (98M52)
V^{47}	A chem, excit, cross bomb (12O42); chem, sep isotopes (26K49)		β^+ (30W37b)	33 m (26K49, 12O42, 30W37b)	1.7 abs (26K49); 2.0 abs (35D46a, calc from 30W37b); ~1.9 abs (12O42, 30W37b)	γ (26K49)		Ti-d-n (30W37b, 12O42); Ti-p-n (12O42) Ti^{47}-p-n (26K49) spall Fe (45R52)
V^{48}	A chem, excit, cross bomb (30W37c, 30W37b)		β^+ 58%, EC 42% (21G46); β^+, EC (30W39, 53H44)	16.0 d (30W37b)	0.69 (~95%), ~0.8 (~5%) spect (43R52); 0.72 spect (6P46); 0.6 abs (53H44) 1.0 cl ch (30W37b)	γ_1 0.99, γ_2 1.32 (γ_2 coinc with γ_1), γ_3 2.29 (γ_3/γ_2 = 0.017) scint spect (69M52); γ_1 0.99, γ_2 1.32, γ_3 2.22 scint spect, β^+-γ, γ-γ coinc (43R52); γ_1 0.98, γ_2 1.33 (γ_2 coinc with γ_1, both coinc with β^+) spect, β-γ coinc (6P46); γ_1 (e/γ 2 x 10^{-4}), γ_2 (e/γ 8 x 10^{-5}) spect conv (72S52); γ_3 2.22 (~2%), no 2.3 γ (lim 0.5%) scint spect (18T52); γ_1 0.99, γ_2 1.32 spect conv (20R49); γ_1 (coinc with γ_2) γ-γ coinc (34J52)	Q_β^+ 4.02 (43R52)  V48 (3,4+) EC, β+ (4) 2.31 (2) 2.22 (2) 0.990 (1.32?) (0+) 0 (43R52)	Sc-α-n (30W37c); Ti-d-n (30W37b); Ti-p-n (2D40, 18T52); Cr-d-α (30W37b, 6P46); spall Fe (45R52), Cu (32M48, 42B51a); daughter Cr^{48} (45R52)
V^{49}	D chem (30W39, 2[illegible]T40); excit (43H49, est from 10C49)		EC (30W39)	635 d (10C49, ~600 d (30W39)		0.119, 0.081 spect conv (10C49)		Ti-d-n (30W39); V-n-2n (?) (10C49)
V^{50}		0.24 (43H49, 28L49)					Q_β^- 1.18, Q_β^+ 2.39 (23J52); V^{50}, I = 6 (56K52)	

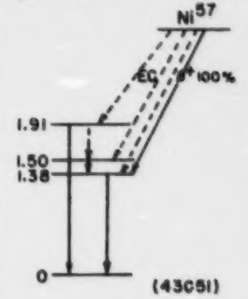
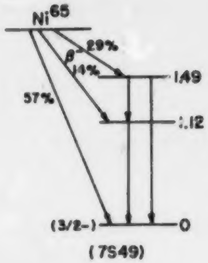
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{23}V^{51}$		99. 76 (43H49, 28L49)					V^{51}, I = 7/2 (87M50, 97B51c)	
$V^{52(m?)}$	A chem, n-capt (12A35); cross bomb, excit (30W37b)		β^- (12A35), IT (25R50)	3. 76 m (38S2); 3. 74 m (42M47); 3. 75 m (12A35)	2. 1 abs (3D40a); 2. 6 cl ch (4Y42); conv: 0. 25, β^- with V^{52}, abs, β-γ, β-conv coinc (25R50)	1. 5 abs (42M47); 1. 3 abs (28G48); ~1. 5 γ with V^{52} (25R50)		V-n-γ (12A35, 30W37b, 1P37, 2S47, 9O49, 25R50, 50H51); V-d-p (30W37b); Cr-n-p (30W37b, 1P37); Cr-γ-p (42H47); Cr^{54}-d-α (15N50); Mn-n-α (12A35, 30W37b, 1P37)
V^{52}	F n-capt (25R50)		β^- (25R50)	2. 6 m (25R50)	2. 7 cl ch (4Y42)	1. 5 abs (42M47)		V-n-γ (25R50)
$V^{52,50m}$	F V^{52}: (10C49); V^{50m}: (43H49)			16 h (10C49)				V-n (10C49)
V^{53}	B chem, sep isotopes, excit (88H52)		β^- (88H52)	23 h (88H52)	~9. 6 abs (88H52)			Cr^{54}-γ-p (88H52)
$_{24}Cr^{48}$	B chem, genet (45R52)		EC (45R52)	~23 h (45R52)				spall Fe, parent V^{48} (45R52)
Cr^{49}	A chem, excit, cross bomb (12O42)		β^+ (12O42)	41. 9 m (12O42); 45 m (34H44)	1. 45 abs, cl ch (12O42)	0. 18, 1. 55 abs (12O42)		Ti-α-n (12O42); Cr-n-2n (12O42); Cr-γ-n (34H44, 12P49); spall Fe (45R52), Co (29W52), Cu (32M48, 42B51a, 74M52), As (48H50)
Cr^{50}		4. 31 (24W48)						
Cr^{51}	A chem, excit, cross bomb (30W40b); chem, genet (50B50)		EC (16B45a, 30W40b); no β^+ (16B45a, 28K49, 35L52)	27. 8 d (35L52); 26. 5 d (30W40b)		0. 330 (~3%, e_K/γ ~0. 02), spect spect conv (16B45a); 0. 32 (8%, e/γ very small) scint spect, x-γ coinc (35L52); 0. 323 spect, spect conv (28K49); 0. 320 (single γ) spect (17K48); 0. 32 spect conv (43M46); others (52M51, 28K49, 13A50b)	 Ti^{51} Cr^{51} 8-10% EC 90-92% β^- 0.32 0 (38M51a, 14S52a, 35L52)	Ti-α-n (30W40b); V-p-n (16B45a); Cr-d-p (30W40b, 22A40); Cr-n-γ (30W40b, 2S47); Cr-n-2n (22A40); spall Fe (45R52), Cu (32M48, 42B51a), As (48H50); daughter Mn^{51} (50B50)
Cr^{52}		83. 76 (24W48)						
Cr^{53}		9. 55 (24W48)					Cr^{53}, I = 3/2 (97B51)	
Cr^{54}		2. 38 (24W48)						
Cr^{55}	G not found: sep isotopes, excit, cross bomb (15N50); chem, excit (32M50)			~2 h (18D40)				Cr-n (18D40, 22A40, 2S47); Cr-d (22A40)

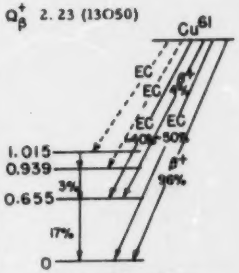
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{25}Mn^{49, 50}$	E excit (39T52, 98M52)		β^+ (98M52)	0. 28 s (98M52); ~0. 5 s (39T52)	>6. 3 scint spect (98M52)			Cr-p-2n (39T52); Cr-p-n (98M52)
Mn^{51}	A chem, cross bomb (12L37, 12L38); chem, genet (50B50)		β^+ (12L37)	44. 3 m (50B50); 46 m (12L38)	2. 4 abs (35B46a, calc from 12L38); 2. 0 abs (12L38)			Cr-d-n (12L38, 50B50); Cr-p-γ (2D38, 5D39); Fe-γ-p2n (42S52); spall Fe (45R52), Cu (32M48, 42B51a, 74M52); parent Cr^{51} (50B50)
Mn^{52m}	A chem (19D37); chem, excit, cross bomb (12L37, 12L38)		β^+ 99+%, IT (?) ~0. 05% (1O47)	21. 3 m (40H40); 21 m (12L38, 19D37)	2. 66 spect (1O47); 2. 2 cl ch (40H40)	1. 46 (coinc with β^+) spect, β-γ coinc (1O47); 0. 392 (0. 05%) (with IT ?) spect conv (1O47)	Q^+_β 5. 1 (1O47)	Cr-p-n (40H40); Fe-d-α (19D37, 12L38); Fe-γ-pn (22E52, 42S52); daughter Fe^{52} (32M48)
Mn^{52}	A chem, excit, cross bomb (12L37, 12L38)		EC 65%, β^+ 35% (21G46)	6. 0 d (29H50); 6. 2 d (84H51); 6. 5 d (12L38); 6 d (32M48)	0. 58 spect (6P46); 0. 75 abs (19T48); 0. 77 cl ch (40H40)	γ_1 0. 73, γ_2 0. 94, γ_3 1. 46 (γ_1 coinc with γ_2 and γ_3, all coinc with β^+) spect, β-γ coinc (6P46)	Q^+_β 4. 7 (6P46)  Mn^52m Mn^52 0.39 0 V^52 β EC β+ 3.13 2.40 or 2.19 1.46 (0+) 0 (18G52, HPS)	Cr-p-n (40H40); Cr-d-2n (6P46); F -d-α (12L38); spall Fe (45R52), Co (29W52), Cu (32M48, 42B51a, 74M52), As (48H50); spall-fission U (6F51)
Mn^{54m}	F sep isotopes (40C51)		β^- (40C51)	2. 1 m (40C51)				Fe^{54}-n-p, Fe^{54}-d-2p (40C51)
Mn^{54}	A chem, excit, cross bomb (12L37, 12L38)		EC (6A38); no β^+, no β^- (12L38, 20D44)	310 d (12L38)		0. 84 spect, x-γ coinc (20D44); 0. 85 abs (12L38)	 (20D44)	V-α-n (12L38); Cr-d-n (12L38); Cr-p-n (2D40); Fe-d-α (12L38, 20D44); spall Fe (45R52), Cu (42B51a)
Mn^{55}		100 (37S36a)					Mn^{55}, I = 5/2 (97B51a)	
Mn^{56}	A chem, n-capt (12A35)		β^- (12A35)	2. 576 h (106B52a); 2. 59 h (12L38, 9B50)	2. 81 (50%), 1. 04 (30%), 0. 65 (20%) spect (7S46c); 2. 86 (60%), 1. 05 (25%), 0. 75 (15%) spect (4E43a); 2. 88, 1. 04 spect (14T41)	γ_1 0. 822, γ_2 1. 77, γ_3 2. 06 ($\gamma_1/\gamma_2/\gamma_3$ = 10/3/2) spect (7S46c); (γ_2/γ_3 = 1. 0) spect (5S51); γ_1 0. 85, γ_2 1. 81, γ_3 2. 13 ($\gamma_1/\gamma_2/\gamma_3$ = 10/3/2) spect, β-γ coinc (4E43a); ~2. 7 (~0. 1%), ~3. 0 (~0. 2%) D-γ-p ion ch (9B50)	Q^-_β 3. 63 (7S46c)  Mn^56 β 20% 30% 50% 2.88 2.59 0.822 ~100% 0 (7S46c, 4E43c)	Cr-α-p (18R37); Mn-n-γ (12A35, 2S47, 9O49, 50H51); Mn-d-p (12L38); Fe-d-α (12L38); Fe-n-p (12A35); Fe-γ-p (12P48, 22E52); Co-γ-2pn (22E52); Co-n-α (12A35); spall Fe (45R52), Co (29W52), Cu (32M48, 42B51a, 74M52), As (48H50)
Mn^{57}	B chem, cross bomb (112S51)		β^- (112S51)	7 d (112S51)	1. 0 spect (112S51)			Mn-α-2p, Cr-α-p (112S51)

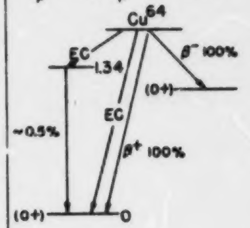
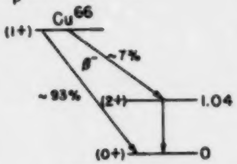
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{26}Fe^{52}$	A chem, genet (32M48)		EC 60%, β^+ 40% (23F51)	8.3 h (23F52b); 7.8 h (32M48)	-0.55 abs (32M48); -0.6 abs (23F51)	no γ >0.5 scint spect (23F51)	 (0+) Fe^{52} EC, β^+ Mn^{52m} Mn^{52} (23F51, HPS)	Cr-α-2n (23F51); Fe-γ-2n (42S52); spall Fe (45R52), Co (29W52), Cu (32M48, 51B50, 23F51, 42B51a, 74M52); parent Mn^{52m} (32M48); not parent Mn^{52} (lim 5%) (23F51)
Fe^{53}	A chem (18R37); chem, excit, cross bomb (12L38a)		β^+ (18R37)	8.9 m (18R37, 12L38a)	2.5 scint spect (52B51); 2.6 abs (15N50)	no γ (15N50)		Cr^{50}-α-n (15N50); Cr-α-n (18R37, 12L38a); Fe-n-2n (12L38a); Fe-γ-n (34H42, 34H44, 52B51, 22E52, 42S52); Fe^{54}-γ-n (12P49); spall Cu (32M48, 42B51a, 74M52)
Fe^{54}		5.84 (6V41)						
Fe^{55}	A chem, excit (12L39a)		EC, no β^+ (16B46b, 94M51)	2.94 y (53B50); 3.0 y (53S51)		no γ (6P46a); -0.07 (0.002%), Mn K-x (16B46b)	Q_{EC} 0.21 continuous γ spectrum (94M51, 94M51a)	Mn-d-2n (51H48); Mn-p-n (2V40, 16B46b); Fe-d-p (12L39a); spall Co (93M51), Cu (42B51a, 93M51); daughter Co^{55} (12L41)
Fe^{56}		91.68 (6V41)						
Fe^{57m}	A genet (20D50)		IT (20D50)	1.1×10^{-7} s delay coinc (20D50)		0.014 spect (20D50)	see Co^{57}	daughter Co^{57} (20D50)
Fe^{57}		2.17 (6V41)						
Fe^{58}		0.31 (6V41)						
Fe^{59}	A chem, excit, cross bomb (12L38a)		β^- (12L38a)	45.1 d (53S51); 47.1 d (22T51); 45.5 d (29G43); 46 d (54S47)	0.460 (~50%), 0.257 (~50%) spect, β-γ coinc abs (20D42); 0.45, no 0.26 β^- spect (48M51)	γ_1 1.295, γ_2 1.097 spect (12H50); γ_1 1.29, γ_2 1.10 (not coinc with γ_1) spect, γ-γ coinc (48M51); 1.30, 1.10 spect (20D42); γ_1 (e_K/γ 0.84×10^{-4}), γ_2 (e_K/γ 1.45×10^{-4}) spect conv (93B52); 0.195 (2.5%, coinc with 1.1 γ) scint spect, γ-γ coinc (44M52); others (52M51)	 (HPS)	Fe-d-p (12L38a, 20D42); Fe-n-γ (26S42, 4W43, 2S47); Co-n-p (12L38a, 2I46); Co-d-2p (17T48); spall Cu (32M48, 51B50, 42B51a, 74M52), As (48H50); spall-fission Ta (22N52), Bi (11G49), U (6F51)
Fe^{60}	E chem (6F51)		β^- (6F51)	8.4 h (6F51)	-1.5 abs (6F51)			spall-fission U (6F51)

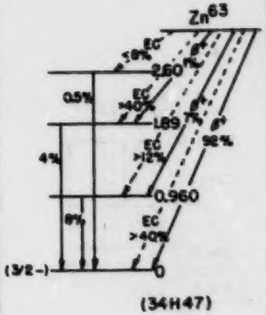
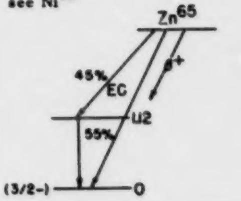
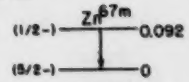
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{27}Co^{54}$	E excit (98M52)		β^+ (98M52)	0.18 s (98M52)	>7.4 scint spect (98M52)			Fe-p-n (98M52)
Co^{55}	A chem (19D37); chem, cross bomb, genet (12L41)		β^+ ~60%, EC ~40% (calc from 20D49)	18.2 h (19D37)	1.50 (~50%), 1.01 (~50%) spect (20D49); 1.50 spect (24L39)	γ_1 0.477 (γ/β^+ 0.3, e/γ 0.0007), γ_2 0.935 (γ/β^+ 1.4, e/γ 0.0005), γ_3 1.41 (γ/β^+ 0.3, e/γ 0.00004) spect, spect conv, β-γ coinc (20D49); others (85S51)	Q_β^+ 3.45 (20D49)  Co^{55} β^+ ~50% EC EC β^+ 50% 1.41 0.935 0 (20D49)	Fe-d-n (19D37, 12L41, 20D49); Fe-p-γ (12L38b, 12L41); Ni-γ-p2n (42S52); spall Fe (45R52), Co (29W52), Cu (32M48, 42B51a, 74M52), As (48H50); parent Fe^{55} (12L41)
Co^{56}	A chem, excit, cross bomb (12L41)		EC, β^+ (4E43a, 28C42)	72 d (12L41); 80 d (28C42)	1.50 (coinc with γ_1 and γ_2) spect (4E43a); 1.2 abs (12L41, 28C42)	γ_1 0.845, γ_2 1.26 (coinc with γ_1), γ_3 1.74, γ_4 2.01, γ_5 2.55, γ_6 3.25 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 1.0/0.5/0.2/0.1/0.2/0.2) spect, β-γ coinc (4E43a); others (85S51)	Q_β^+ 4.6 (4E43a)	Fe-d-2n (12L41, 16J41, 21P42, 4E43a); Fe-α-np (12L41); Co-p-p3n (29W52); Ni-d-α (12L41, 28C42, 4E43a): Ni-γ-pn (42S52); spall Fe (45R52), Cu (42B51a); daughter Ni^{56} (44S52, 32W52)
Co^{57}	A chem, excit, cross bomb (12L41)		β^+ (12L41)	270 d (12L41)	0.26 abs (12L41)	0.119, 0.131 spect (4E43a); 0.117 (e/γ large, K/L 7), 0.130 (e/γ large, K/L 7) spect, spect conv (21P42); with Fe^{57m}: 0.014 spect (20D50)	Q_β^+ 1.4 (HPS)  (7/2-) Co^{57} β^+ Fe^{57m} 0.131 0.014 (3/2-) 0 (18G52)	Fe-d-n (12L38b, 22P38, 54B39, 12L41); Fe-p-γ (12L41); parent Fe^{57m} (20D50); daughter Ni^{57} (23F52)
Co^{58m}	A chem, excit (55S50)		IT, no β^+ (55S50)	9.2 h (25C50); 9.0 h (37A52); 8.8 h (55S50)		0.025 (e/γ large, K/L 1.9) spect conv (55S50)		Mn-α-n, Co-d-p2n, Co-n-2n, Ni-n-p, Ni-d-2p (55S50); Fe^{58}-p-n (37A52); Co-γ-n (25C50); spall Cu (55S50, 74M52)
Co^{58}	A chem, excit, cross bomb (12L41)		EC 85%, β^+ 15% (21G46)	72 d (12L41)	0.47 spect (20D44); 0.4 abs (12L41)	0.81 spect, β-γ coinc (20D44); ~0.81 (e/γ 0.0003) spect conv (55S50); 0.6 abs (12L41)	Q_β^+ 2.3 (18G52)  (5+) Co^{58m} 0.025 (2+) Co^{58} 0 β^+ EC (1,2+) 0.81 ~100% (0+) 0 (18G52)	Mn-α-n (12L38b, 12L41); Fe-d-n (12L36b, 22P38, 54B39, 12L41); Fe^{58}-p-n (37A52); Fe-p-n (12L38b); Fe-α-np (12L41); Fe-p-γ (12L41); Co-p-pn (29W52); Ni-n-p (7V38, 12L41, 20D44); spall Cu (51B50, 42B51a, 74M52), As (48H50)
Co^{59}		100 (45M41)					Co^{59}, I = 7/2 (87M50, 97B51d)	

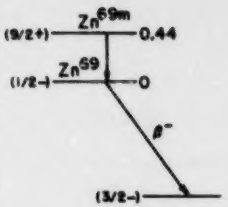
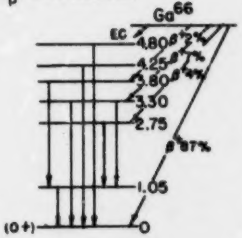
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{27}Co^{60m}$	A n-capt (6H37a); chem, excit, cross bomb (12L41)		IT 99+%, β^- 0. 28% (20D51)	10. 1 m (106B52b); 10. 7 m (12L41)	1. 56 spect (6P47); 1. 35 spect (15N42); 1. 28 spect (20D45)	0. 0589 (K/L 4. 6) spect conv (42C50); 0. 059 scint spect (31K51); 0. 056 spect conv (20D45)	Q_β^- 2. 89 (HPS)  Co60m Co60 (2+) (5+) 0.058 0 β- (4+) 2.50 (2+) 1.33 (0+) 0	Co-n-γ (6H37a, 12L37, 12L41, 20D42a, 2S47); Co-d-p (15N42); Ni-n-p (6H37b, 12L41)
Co^{60}	A n-capt (37S36); chem, excit, cross bomb (12L41)		β^- (27R37)	5. 27 y (22T51); 5. 3 y (12L41, 53B50, 38S51)	0. 306 spect (29F52); 0. 318 spect (31W50a); 0. 310 spect (43M47)	γ_1 1. 3316, γ_2 1. 1715 cryst spect (29L49); 1. 3316, 1. 1715 spect γ-γ coinc (16D51); γ_1 (e/γ 1. 24 x 10^{-4}), γ_2 (e/γ 1. 72 x 10^{-4}) spect conv (29F52); γ_1 (e/γ 1. 29 x 10^{-4}), γ_2 (e/γ 1. 73 x 10^{-4}) spect conv (31W50, 31W50a); γ_1 (e/γ 1. 8 x 10^{-4}), γ_2 (e/γ 2. 3 x 10^{-4}) spect conv (7S50); others (17B50, 44M50a, 13A49, 36A52, 37D51, 85B50a, 85S51)	Q_β^- 2. 81 (HPS) (20D51, 29F52, 18G52)	Co-d-p (12L38b, 54B39, 12L41, 20D42a, 15N42); Co-n-γ (27R37, 12L38b, 12L41, 2S47, 1Y51); Ni-d-α (12L41); Cu-n-α (12M46c); spall-fission Bi (66B51)
Co^{61}	A chem, excit, cross bomb, sep isotopes, mass spect (23P47)		β^- (23P47)	99. 0 m (56S51); 105 m (23P49); 110 m (48H50)	1. 42 (~55%), 1. 00 (~45%) abs (56S51); 1. 3 abs (23P49)	~0. 5 abs (56S51); no γ (23P49, 29K48)	Q_β^- 1. 4 (HPS)	Co-α-2p (112S51); Co-t-p (29K48); Ni-γ-p (12P48, 56S51, 22E52); Ni^{64}-p-α (23P47, 23P49); Ni^{61}-n-p (23P47, 23P49); Ni-d-αn, Cu-n-αn (23P47, 23P49); Cu-γ-2p (12P48); Cu-γ-α (49H51); spall Cu (32M48, 42B51a, 74M52), As (48H50); spall-fission Ag (42B51), U (6F51)
Co^{62}	A chem, sep isotopes (23P49)		β^- (23P49)	13. 9 m (23P49)	2. 3 abs (23P49)	1. 3 (coinc with β^-) abs, β-γ coinc (23P49)		Ni^{62}-n-p (23P49)
Co^{62}	E cross bomb, sep isotopes (23P49)		β^- (23P49)	1. 6 m (23P49)		γ (23P49)		Ni^{62}-n-p, Ni^{64}-d-α (23P49)
Co^{64}	F cross bomb, sep isotopes (23P49)			~5 m (23P49)				Ni^{64}-n-p (23P49)
$_{28}Ni^{56}$	A chem (32W52); chem, sep isotopes, genet (44S52)		EC ~100%, no β^+ (lim 1%) (44S52)	6. 4 d (44S52); 6. 0 d (32W52)		γ_1 0. 17, γ_2 0. 28, γ_3 0. 48, γ_4 0. 81, γ_5 0. 96, γ_6 1. 33, γ_7 1. 58, γ_8 1. 75 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7/\gamma_8$ = 1. 0/0. 3/0. 4/0. 8/0. 1/0. 05/0. 15/0. 02) scint spect (44S52); 0. 14, 0. 77, >1. 4 scint spect (32W52)		Fe-α-2n (32W52); Fe^{54}-α-2n (44S52); spall Zn (32W52); parent Co^{56} (44S52, 32W52)

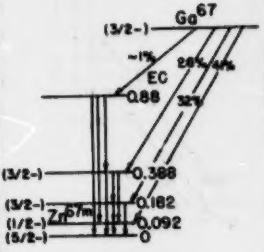
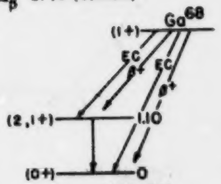
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{28}Ni^{57}$	A chem, excit, cross bomb (12L38c)		β^+ 50%. EC 50% (23F50)	36 h (46M49, 12L38c)	0. 835 spect (43C51); 0. 845 spect (23F50)	γ_1 1. 91, γ_2 1. 38 (γ_2/γ_1 = 6) spect (43C51); γ_1 1. 90, γ_2 1. 39 (γ_2/γ_1 = 5) scint spect (44S52); 0. 128 spect, spect conv (43C51); 0. 120, 1. 9 scint spect, spect conv, β-γ coinc (23F50)	Q_β^+ 3. 24 (43C51)  Ni^{57} EC β^+ 100% 1.91 1.50 1.38 0 (43C51)	Fe-α-n (12L38c, 14D41, 15N42a, 46M49, 23F50, 43C51); Co-p-3n (29W52); Ni-n-2n (12L38c, 14D41, 15N42a, 80M52); Ni-He^3-α (1P52); Ni-γ-n (34H44, 12P48, 12P49, 22E52, 42S52); spall Cu (32M48, 42S51a, 74M52), As (48H50); parent Co^{57} (23F52)
Ni^{58}		67. 76 (24W48)						
Ni^{59}	A chem, cross bomb, n-capt (44C45); chem, sep isotopes, n-capt (48B51)		EC (23F49)	8 x 10^4 y yield (48B51); 8 x 10^5 y yield (33W51); ~3 x 10^5 y yield (23F49)		Co-K-x, no γ (33W50, 33W51); Co-K-x (48B51, 23F49)		Fe-α-n (44C45); Co-d-2n (48B51); Ni-n-γ (44C45, 33W50); Ni^{58}-n-γ (48B51); Ni-d-p (44C45)
Ni^{60}		26. 16 (24W48)						
Ni^{61}		1. 25 (24W48)						
Ni^{62}		3. 66 (24W48)						
Ni^{63}	A chem, n-capt, sep isotopes (48B51)		β^- (23F49, 48B51)	85 y yield (48B51); 61 y yield (33W51)	0. 067 ion ch (48B51); 0. 063 ion ch (33W49)			Ni-n-γ (23F49, 33W49, 33W50, 48B51); Ni^{62}-n-γ (48B51)
Ni^{64}		1. 16 (24W48)						
Ni^{65}	A n-capt (6R35); chem, sep isotopes, excit (54S46, 45C46)		β^- (6H37b)	2. 564 h (57S49); 2. 6 h (12L38c, 46M49)	2. 10 (57%), 1. 01 (14%), 0. 60 (29%) spect (7S49)	1. 49, 1. 12, 0. 37 spect, β-γ, γ-γ coinc (7S49); others (54W51)	Q_β^- 2. 10 (7S49)  Ni^{65} β^- 29% 14% 57% 1.49 1.12 (3/2-) 0 (7S49)	Ni-d-p (12L38c, 15N42a); Ni-n-γ (6H37b, 14D41, 15N42a, 2S47, 46M49); Ni^{64}-n-γ (45C46); Cu-n-p (6H37b); Cu^{65}-n-p (54S46); Cu^{65}-t-He^3 (29K51); Cu-d-2p (32M48, 51B50); Zn-n-α (6H37b); spall Cu (74M52), As (48H50); spall-fission Ta (22N52), Bi (11G49), U (6O48, 6F51)
Ni^{66}	A chem, genet (11G49)		β^- (11G49)	56 h (11G49, 48H50)				spall As (48H50); spall-fission Ta (22N52), Bi (11G49), U (6F51); parent Cu^{66} (11G49)

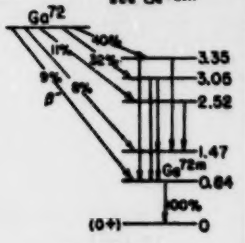
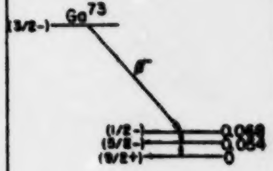
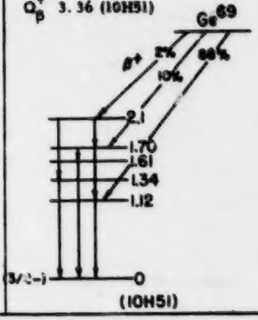
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{29}Cu^{58}$	B chem (5D39); chem, excit, sep isotopes (30L47)		β^+ (5D39)	7.9 m (5D39); 10 m (30L47)				Ni-p-n (5D39); Ni^{58}-p-n (30L47)
Cu^{58}	C excit (39T52, 98M51)		β^+ (98M51)	3.04 s (98M51); 2.6 s (39T52)	>7.5 scint spect (98M51)			Ni-p-n (39T52, 98M51)
Cu^{59}	E chem (5D39); excit, sep isotopes (30L47)		β^+ (5D39)	81 s (5D39, 30L47)				Ni-p-γ (5D39); Ni^{58}-p-γ (30L47)
Cu^{60}	A chem, excit, sep isotopes, mass spect (30L47)		β^+ (30L47)	24.6 m (30L47)	1.8, 3.3 (<5%) abs (30L47)	1.5 abs (30L47)		Ni-p-n (30L47); Ni^{60}-p-n, Ni^{60}-d-2n, Ni^{58}-α-pn (30L47); spall Cu (42B51a), As (48H48a)
Cu^{61}	A chem, excit (18R37a); chem, excit, sep isotopes (30L47, 29K50)		β^+ 68%, EC 32% (28C51); β^+ 72%, EC 28% (55B50); β^+ 75%, EC 25% (34H49)	3.33 h (28C48b); 3.4 h (6T37a, 18R37, 29K50); 3.3 h (48H50)	1.205 (96%), 0.55 (4%) spect (13050); 1.23 spect (16B45b)	γ_1 0.655 (γ/β^+ 0.25, e/γ ~0), γ_2 0.284 (γ/β^+ 0.05, e/γ 0.015), γ_3 0.076 (γ/β^+ 0.01, e/γ large) spect, spect conv (13050); γ_1 (17%), γ_2 (3%), γ_3 (~0.6%) (calc from 28C51, 13050); 0.652, 0.279, 0.070 (K/L ~10) spect, spect conv (56B50)	Q_β^+ 2.23 (13050)  Cu61 EC EC 4% β+ EC 40% EC 50% β+ 96% 1.015 0.939 0.655 3% 17% 0 (13050, 28C51, HPS)	Ni-d-n (6T37a); Ni-p-n, Ni-p-γ (58S38, 5D39); Ni^{61}-p-n (30L47); Ni-He^3-d (1P52); Ni-α-p (18R37, 29K50); Cu-γ-2n (12P48, 22E52); Zn-γ-p2n (55S51, 42S52); spall Cu (32M48, 42B51a, 74M52), As (48H50); spall-fission Bi (66B51), U (6F51)
Cu^{62}	A excit (6H37a); excit, cross bomb (18R37, 58S38, 37B39); chem, sep isotopes (30L47)		β^+ (6H37a)	10.1 m (30L47); 10.0 m (18R37); 9.9 m (12P48); 10.5 m (6H37a)	2.92 spect (61H50); abs (30K50); 2.83 spect (25B49)	0.56 abs (19T47)		Co-α-n (18R37); Ni-p-n, Ni-p-γ (58S38); Ni^{60}-α-pn (48G50); Cu-n-2n (6H37b, 80M52, 30B52); Cu-p-pn (48G50); Cu-γ-n (37B39, 34H43, 34H43b, 55K52, 25B49, 12P48, 22J50, 55S51, 22E52); Cu-e^--e^-n (59S48); Cu-d-t (9K40a, 9K41a); Zn-γ-pn (55S51, 22E52, 42S52); spall Cu (32M48, 42B51a, 74M52), As (48H50); daughter Zn^{62} (32M48)
Cu^{63}		69.1 (57B47)					Cu^{63}, I = 3/2 (87M50)	

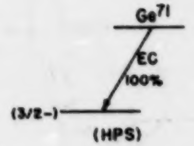
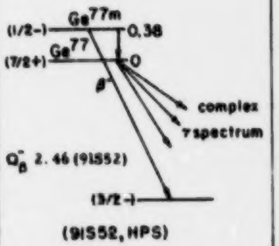
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{29}Cu^{64}$	A chem, n-capt (12A35); excit (2V36); chem, excit (5D39)		EC 42%, β^- 39%, β^+ 19% (HPS, calc from average of K/β^+ and β^-/β^+); K/β^+ 2.2 (24P51); K/β^+ 2.3 (28R50); K/β^+ 1.8 (34H49); K/β^+ 2.7 (55B50); β^-/β^+ 2.0 (55B49, 28C48c); β^-/β^+ 2.1 (16B46a); $\frac{\beta^+ + EC}{\beta^-}$ 1.62 (28R50)	12.80 h (29R50); 12.74 h (53S51); 12.88 h (57S49); 12.8 h (2V36, 48H50)	β^-: 0.571 spect (28C48c, 13O49); 0.570 spect (6P47); 0.58 spect (20T39, 14T41) β^+: 0.657 spect (28C48c, 13O49); 0.644 spect (6P47); 0.65 spect (14T41); 0.66 spect (20T39)	γ (with EC) coinc (16B46a); γ (1% of EC) (HPS, calc from 20D47, 27K50, 28R50); 1.34 (weak) spect (17K48); 1.35 (γ/β^+ 0.025) spect (20D47); 1.33 scint spect (11B50d); (γ/β^+ 0.023) abs (10V52); 1.38 (γ/β^+ 0.032) abs (27K50); -1.34 (e_K/γ -1.3 x 10^{-4}) spect conv (93B52); γ (e/γ <0.005) spect conv (47M48)	Q_β^- 0.57, Q_β^+ 1.68 (HPS)  Cu64 EC 1.34 β⁻ 100% (0+) ~0.5% EC β⁺ 100% (0+) 0 (HPS)	Ni-p-n (58S38, 5D39); Ni-He^3-p (1P52); Cu-d-p (2V36); Cu-n-γ (6H37b, 2S47); Cu-n-2n (6H37b, 74M52); Cu-p-pn (23R46, 42B51a); Cu-t-d (29K51); Cu-γ-n (34H43b, 34H44, 22J50, 12P49, 55S51, 22E52); Zn-n-p (12A35, 6H37b); Zn-γ-pn (55S51, 22E52); spall Cu (32M48, 42B51a), As (48H50); spall-fission Bi (66B51), U (6F51)
Cu^{65}		30.9 (57B47)					Cu^{65}, I = 3/2 (87M50)	
Cu^{66}	A n-capt (12A35); excit (7C37)		β^- (12A35)	5.10 m (3S52); 5.12 m (53S51); 5.17 m (30R51); 5.18 m (46C50); 5.2 m (23F51a)	2.63 (91%), 1.5 (9%) spect (23F51a); 2.7 (~94%), 1.65 (~6%) scint spect, β-γ coinc (30R51)	1.044 (γ/β^- 0.10, e/γ <3 x 10^{-3}) spect, spect conv (23F51a); 1.05 scint spect (30R51, 94M51a)	Q_β^- 2.63 (23F51a)  Cu66 (1+) β⁻ ~7% ~93% (2+) 1.04 (0+) 0 (23F51a, 30R51)	Cu-n-γ (12A35, 2S47, 9O49, 50H51); Cu-d-p (31L40); Zn-n-p (6H37b); Cu-n-α (7C37); daughter Ni^{66} (11G49)
Cu^{67}	A chem (11G49); chem, cross bomb, sep isotopes (29K50)		β^- (11G49)	58.5 h (29K50); 61.0 h (80S52); 56 h (11G49); 61 h (48H50)	0.38 (67%), 0.57 (33%) spect (80S52); 0.54 abs (29K50)	0.191 (e/γ 0.01, K/L ~8), 0.096 (e/γ 0.09, K/L 7.4) scint spect, spect conv, β-γ coinc (80S52)	see Ga^{67}	Ni^{64}-α-p (29K50); Cu-α-2p (112S51); Cu-t-p (29K51); Zn^{67}-n-p (29K50); Zn-γ-p (23D48, 55S51, 22E52) spall As (48H50); spall-fission Bi (1[illegible]49, 66B51), U (6F51)
$_{30}Zn^{62}$	A chem, genet (32M48); excit (48G50)		EC ~90%, β^+ ~10% (61H50)	9.33 h (61H50); 9.5 h (32M48)	0.66 spect (61H50)	0.0418 (K/L >6) spect conv (61H50)		Ni-He^3-n (1P52); Ni^{60}-α-2n (48G[illegible]); Cu-p-2n (48G50); Zn-γ-2n (55S51, 22E52, 42S52); spall Cu (32M48, 61H50, 51B50, 42B51a), As (48H50); parent Cu^{62} (32M48)

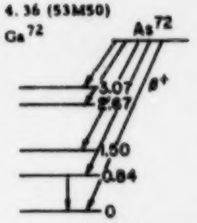
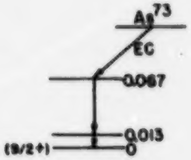
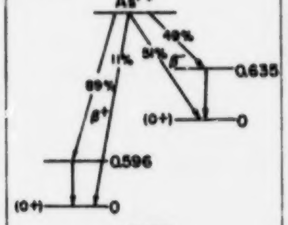
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
${}_{30}Zn^{63}$	A chem, excit (37B37, 6H37b, 18R37)		β^+ 93%, EC 7% (34H47)	38.3 m (34H47, 58S38); 38.5 m (5D39)	2.36 (92%), 1.40 (7%), 0.5 (~1%) spect (34H47); 2.32 spect (14T41)	0.960 (~8%, e/γ 2 x 10^{-4}), 1.89 (~4%, e/γ ~0), 2.60 (~0.5%, e/γ ~0) spect, spect conv, abs, γ-γ coinc (34H47)	Q^+_β 3.38 (34H47)  Zn63 EC ≤8% 2.60 β+ 7% 0.5% EC >40% 1.89 β+ 92% EC >12% 4% 0.960 8% EC >40% (3/2-) 0 (34H47)	Ni-a-n (18R37); Ni^{60}-a-n (48G50); Cu-p-n (58B38, 5D39, 47B51b, 48G50); Cu-d-2n (3[illegible]40, 14T41); Zn-n-2n (6H37b, 1P37); Zn-γ-n (37B39, 12P49, 55S51, 22E52, 42[illegible]52); Zn-γ-3n (55S51); spall Cu (32M48, 51B50, 42B51a), As (48H50)
Zn^{64}		48.89 (1B50)					Zn^{64}, I = 0 (87M50)	
Zn^{65}	A chem (22P38); chem, excit, cross bomb (12L39)		EC (K) 97.5%, β^+ 2.5% (95M52, 4Y52) EC 99+%, β^+ 0.7% (calc from 30G51, 24F51, 21G46a)	250 d (12L39); 245 d (22P38)	0.325 spect (48M49); 0.32 spect (6P47)	1.120 spect conv (48M49); 1.125 spect, spect conv (12H50); 1.114 spect (48M49); 1.112 (e/γ 2.3 x 10^{-4}) spect conv (31W50); 1.127 scint spect (25G51a); 1.12 spect (13J49); γ (46% of EC) x-e coinc (21G46a); γ (44% of EC) x-γ coinc (24F51); $\gamma/\beta^+ \simeq 65$ γ-γ coinc (30G51); 0.21 (coinc with β^+, e/γ ~0.1) β-γ, β-conv coinc (47C50)	see Ni^{65}  (21G46a, 24F51, 95M52)	Cu-d-2n (22P38); Cu-p-n (58B38, 47B51b); Cu-t-n (29K51); Zn-d-p (12L39); Zn-n-γ (42S39, 2S47); spall Cu (42B51a), As (48H50); daughter Ga^{65} (12L39b)
Zn^{66}		27.81 (1B50)					Zn^{66}, I = 0 (87M50)	
Zn^{67m}	A genet (48B53, 47M52)		IT (47M52, 48B53)	8.5 x 10^{-6} s delay coinc (48B53); 9 x 10^{-6} s delay coinc (47M52)		0.092 (e_K/γ 0.63, K/L 7) scint spect (48B53); 0.092 (e/γ 0.6) scint spect (47M52)	see Ga^{67}  (48B53)	daughter Ga^{67} (48B53, 47M52)
Zn^{67}		4.11 (1B50)					Zn^{67}, I = 5/2 (87M50, 38D52)	
Zn^{68}		18.56 (1B50)					Zn^{68}, I = 0 (87M50)	

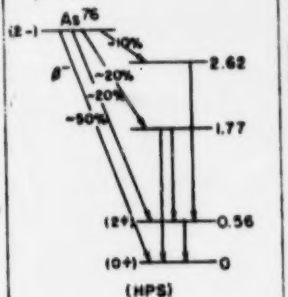
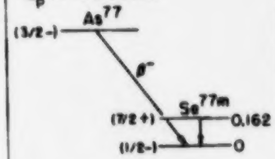
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{30}Zn^{69m}$	A chem, excit (6T38); chem, excit, cross bomb (12L39, 14K39)		IT (14K39)	13.8 h (12L39)		0.437 (e/γ 0.049) spect conv (91S52b); 0.436 (e/γ -0.065) spect conv, scint spect (23D52); 0.439 (e/γ -0.04) spect, spect conv (2H41); 0.440 spect (28G41); 0.450 (e/γ -0.06) (16N44)	 Zn^{69m} (9/2+) 0.44 Zn^{69} (1/2-) 0 β^- (3/2-)	Zn-d-p (12L39, 14K39, 6V39); Zn-n-γ (6T38, 12L39, 2S47); Ga-d-α (12L39); Ga-n-p (12L39); spall As (48H50); parent Zn^{69} (14K39)
Zn^{69}	A chem, n-capt (6H37b); chem, excit, cross bomb (12L39, 14K39)		β^- (6H37b)	57 m (12L39); 51 m (48H48b); 52 m (7H49)	0.897 spect (23D52); 0.914 spect (91S52b); others (14K39, 12L39, 35B46a)	no γ (12L39)	(18G52) Q_β^- 0.90 (HPS, 12L39)	Zn^{70}-γ-n (7H49); Zn-d-p (12L39, 14K39, 6V39); Zn-n-γ (6H36, 6T38, 2S47, 50H51, 42S39); Ga-d-α (12L39); Ga-n-p (12L39); spall As (48H48a); daughter Zn^{69m} (14K39)
Zn^{70}		0.62 (1B50)						
Zn^{71}	E n-capt, cross bomb (28H46b)		β^- (28H46b)	2.2 m (28H46b)	2.1 abs (28H46b)			Zn-n-γ, Ge-n-α (28H46b)
Zn^{72}	A chem, genet (60S46, 60S51)		β^- (60S51)	49.0 h (60S51)	-0.3 (95%), -1.6 (5%) abs (60S51)	γ (60S51)		As-p-4p (112S51); spall As (48H50); spall-fission Bi (11G49), U (6F51); fission Th (21T51), U (60S51), Pu (61S51a); parent Ga^{72} (60S51)
$_{31}Ga^{65}$	A chem, genet (12L39b)		EC (6A38); β^+ >50% (25A52)	15 m (6A38, 12L39b)	2.2 (25A52)	0.054, 0.117 spect conv (6V39)		Cu-He^3-n (1P52); Zn-d-n (6A38, 12L39b); Zn-p-γ (2D40); parent Zn^{65} (12L39b)
Ga^{66}	A chem, excit (50M37, 18R37a)		β^+ 64%, EC 36% (49M52); β^+ 66%, EC 34% (10L50a)	9.45 h (10L50a); 9.4 h (18R37, 59B38); 9.2 h (49M50, 50M37)	4.144 (87%), 1.4 (4%), 0.88 (7%), 0.40 (2%) spect (10L50a); 4.15 (87%), 1.38 (4%), 0.90 (7%), 0.40 (2%) spect (49M52)	γ_1 1.05, γ_2 1.7, γ_3 2.2, γ_4 2.75 coinc with γ_1), γ_5 3.3, γ_6 4.25, γ_7 4.8 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7$ = 3.7/0.3/0.5/2.9/0.5/0.2/0.2) spect, γ-γ coinc abs (49M52); γ_1 1.04, γ_2 1.38, γ_3 1.90, γ_4 2.17, γ_5 2.40, γ_6 2.75, γ_7 3.24, γ_8 3.41, γ_9 3.78, γ_{10} 4.12, γ_{11} 4.33, γ_{12} 4.83 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7/\gamma_8/\gamma_9/\gamma_{10}/\gamma_{11}/\gamma_{12}$ = -1.5/-0.2/0.14/0.24/0.10/1.00/0.09/0.14/0.08/0.07/0.21/0.09) scint spect, pair scint spect (58M52); 1.06, 2.75, 3.25, 4.27, 4.8 scint spect (55H50); 1.03, 2.75, 4.8 spect, spect conv (10L50a)	Q_β^+ 5.16 (23F51a)  Ga^{66} EC 4.80 β^+ 2% 4.25 β^+ 7% 3.80 β^+ 4% 3.30 2.75 β^+ 87% 1.05 (0+) 0 (49M52)	Cu-α-n (50M37, 18R37, 10L50a); Zn-p-n (59B38, 49M50); spall Cu (second order reaction) (42D51a, 29W52), spall As (48H50); spall-fission Sn, Ba (42B51); daughter Ge^{66} (48H49)

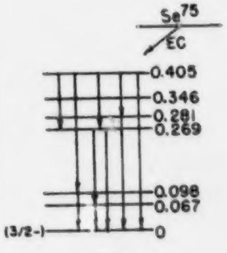
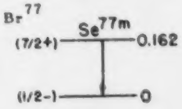
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{31}Ga^{67}$	A chem, excit (50M38a, 50M38); chem, excit, cross bomb (6A38)		EC (6A38); no β^+ (lim 0.01%) (47M52); no β^+ (49M52, 48B53)	77.9 h (22T51); 78.2 h (51M48)		γ_1 0.090 (e_K/γ 0.074), γ_2 0.092 (with Zn^{67m}, e_K/γ 0.63, K/L 7), γ_3 0.182 (e_K/γ 0.011, K/L -12.5), γ_4 0.206 (e_K/γ 0.029, K/L -14), γ_5 0.296 (e_K/γ 0.0029), γ_6 0.388 (e_K/γ 0.0019), γ_7 0.496, γ_8 0.790, γ_9 0.880 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7/\gamma_8/\gamma_9$ = 0.073/1.00/0.81/0.021/0.54/0.13/0.004/0.002/0.004) spect conv, scint spect, conv-γ, γ-γ coinc (48B53); γ_2 0.092 (e/γ 0.28, K/L 6.5), γ_3 0.182 (e/γ 0.0091, K/L 9), γ_4 0.205 (e/γ 0.0055), γ_5 0.298 (e/γ 0.0025), γ_6 0.388 (e/γ 0.0017) ($\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 62/21/2/12/3) spect, spect conv, conv-γ coinc (49M52); γ_1 0.090 (4%), γ_2 0.092 (with Zn^{67m}, 46%, e/γ 0.6), γ_3 0.182 (21.5%), γ_4 0.20 (2%), γ_5 0.30 (12.5%), γ_6 0.39 (4.5%), γ_7 -0.50 (<1%), γ_9 -0.85 (<1%), γ_{10} -1.05 (<1%) scint spect, γ-γ coinc (47M52); others (2H41, 10C42, 28G41, 7S52)	 Ga67 (3/2-) ~1% EC 28% 4% 0.88 32% (3/2-) 0.388 (3/2-) Zn67m 0.182 (1/2-) 0.092 (5/2-) 0 (48B53)	Cu-α-γ (112S51); Cu-He³-n (1P52); Zn-d-n (6A38, 31G38, 6V39); Zn-α-p (50M38); Zn-p-n (59B38, 6V39); Ge-γ-p2n (42S52); spall Cu (second order reaction) (42B51a), As (48H50); daughter Ge^{67} (48H49); parent Zn^{67m} (48B53, 47M52)
Ga^{68}	A chem, excit (37B37); chem, excit (18R37)		β^+ -85%, EC -15% (49M52)	68 m (18R37, 12P48)	1.88 (-96%), 0.77 (-4%) spect (49M52); 2.0 abs (35B46a, calc from 50M37); 1.9 abs (18R37, 50M37); cl ch (50M37)	1.10 spect (49M52)	Q_β^+ 2.90 (49M52)  Ga68 (1+) EC β+ EC β+ (2,1+) 1.10 (0+) 0 (49M52)	Cu-α-n (18R37, 50M37); Zn-p-n (2D38, 59B38, 49M50); Zn-p-γ (?) (2D38); Zn-d-n (31G38, 6V39); Ga-n-2n (1P37); Ga-γ-n (37B37, 37B39, 12P48); Ge-γ-pn (12P49, 42S52); Ge-d-α (42S41); spall Cu (second order reaction) (42B51a, 29W52), spall As (48H50); daughter Ge^{68} (48H48a)
Ga^{69}		60.2 (3I48)					Ga^{69}, I = 3/2 (87M50)	
Ga^{70}	A chem, n-capt (12A35); chem, excit (2D38)		β^- (2D38)	20.3 m (61B47); 20 m (12A35)	1.65 spect (56H48); 1.62 abs (61B47); -1.6 cl ch (42S39a)			Zn-p-n (2D38); Zn-α-p (50M38); Ga-n-γ (12A35, 2S47); Ga-n-2n (1P37); Ga-γ-n (37B39, 12P48); Ge-d-α (42S41); Ge-n-p (42S41); As-γ-αn (85H52); spall As (48H50)
Ga^{71}		39.8 (3I48)					Ga^{71}, I = 3/2 (87M50)	

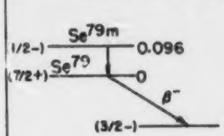
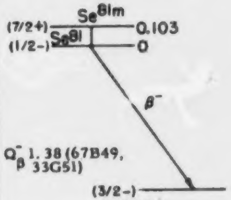
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{31}Ga^{72}$	A chem, n-capt, excit (12L38a, 42S39)		β^- (42S39)	14. 3 h (26M43a, 60S51); 14. 1 h (42S39, 9B50)	3. 15 (9%), 2. 52 (8%), 1. 5 (11%), 0. 9 (32%), 0. 6 (40%) spect (56H48); 3. 17 (8%), 2. 57 (8%), 1. 7 (?) (3%), 1. 5 (?) (7%), 1. 00 (26%), 0. 74 (23%), 0. 6 (?) (25%) spect (14M48)	γ_1 2. 491, γ_2 2. 508 (γ_1/γ_2 0. 63) spect (12H52); 2. 51 (26%), 2. 21 (33%), 1. 87 (8%), 1. 59 (5%), 1. 20 (?) (<2%), 1. 05 (5%), 0. 84 (100%), 0. 68 (<2%), 0. 63 (24%) spect, spect conv (56H48); $\gamma_1\gamma_2$ 2. 50 (15%), γ_3 2. 18 (33%), γ_4 1. 81 (10%), γ_5 1. 57, γ_6 1. 47, γ_7 1. 30 ($\gamma_5 + \gamma_6 + \gamma_7$ 28%), γ_8 1. 05 (15%), γ_9 0. 835 (100%), γ_{10} 0. 691 (5%), γ_{11} 0. 631 (54%) spect, spect conv (14M48); 3. 4 (~0. 03%), 3. 1 (~0. 1%) D-γ-p ion ch (9B50)	Q_β^- 4. 0 (56H48, 14M48) see Ge^{72m}  Ga72 40% 11% 32% 9% 6% β⁻ 3.35 3.05 2.52 1.47 Ge72m 0.84 100% (0+) 0 (56H48, HPS)	Ga-d-p (12L38a); Ga-n-γ (42S39, 2S47, 60S51); Ge-α-p (42S41, 60S51); As-d-αp (16C47); As-γ-He^3, As-γ-2pn (85H52); spall-fission Sn, Ba (42B51), Tl (2T47b), Bi (11G49, 13P47), U (6O47, 6F51); fission Th (21T51), U (60S51); daughter Zn^{72} (60S51); parent Ge^{72m} (28B48)
Ga^{73}	B chem, excit (60S46, 60S51)		β^- (60S51)	5. 0 h (60S51)	1. 4 abs (60S51)	0. 0135, 0. 054 spect conv (17J51a)	 (3/2-) Ga73 β⁻ (1/2-) (5/2-) (9/2+) 0.068 0.054 0 (17J51a)	Ge-n-p (60S51); Ge-γ-p (12P49); As-γ-2p (85H52); As-α-α2p (112S51); spall-fission Bi (11G49); fission U (60S51)
$_{32}Ge^{66}$	A chem, genet (48H49)		β^+ (?) (48H50)	~150 m (48H50)				spall Cu (second order reaction) (42B51a), spall Ge (48H49), As (48H50); parent Ga^{66} (48H49)
Ge^{67}	A chem, genet (48H49)		β^+ (48H50)	21 m (48H50)				spall Cu (second order reaction) (42B51a), spall Ge (48H49), As (48H50); parent Ga^{67} (48H49)
Ge^{68}	A chem (50M38); chem, genet (48H48b)		EC (48H48b)	250 d (48H50)				spall Cu (second order reaction) (42B51a), spall As (48H48a, 48H50); Zn-α-2n (50M38); parent Ga^{68} (48H48a, 48H50)
Ge^{69}	A chem (50M38); chem, excit, cross bomb (51M48)		EC ~67%, β^+ ~33% (51M48); β^+ (50M38)	39. 6 h (51M48); 39. 7 h (12D42); 40 h (48H50); 37 h (50M38)	1. 215 (88%), 0. 610 (10%), 0. 22 (2%) spect (10H51)	1. 610, 1. 340, 1. 12, 0. 870, 0. 576, 0. 388, 0. 090 spect, β-γ coinc (10H51)	Q_β^+ 3. 36 (10H51)  Ge69 β⁺ 2% 10% 88% 2.1 1.70 1.61 1.34 1.12 (3/2-) 0 (10H51)	Zn-α-n (50M38, 51M48); Ga-d-2n (13S41a, 51M48, 10H51); Ga-p-n (12D42); Ge-n-2n (42S41, 51M48); Ge-γ-n (34H44, 42S52); spall As (48H50)

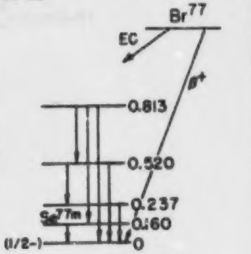
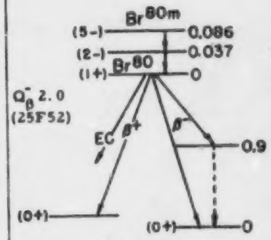
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma transitions		
$_{32}Ge^{70}$		20.55 (3I48a)					Ge^{70}, I = 0 (35T49)	
Ge^{71}	A chem, excit, cross bomb (13S41a); sep isotopes, n-capt (22R50)		EC, no β^+ (51M48, 26M49)	11.4 d (51M48); 11.3 d (12D42); 11 d (26M49, 13S41a)		no γ (13S41a, 26M49, 51M48); Ga K-x (2S47, 51M48, 26M49)		Ga-d-2n (13S41a, 51M48); Ga-p-n (12D42); Ge-d-p (13S41a, 51M48); Ge-n-γ (2S47, 51M48, 26M49); Ge^{70}-n-γ (22R50); spall As (48H50); daughter As^{71} (48H49)
Ge^{72m}	A genet (28B48)		IT (28B48)	2.9×10^{-7} s delay coinc (52M51); 5×10^{-7} s delay coinc (28B48)		0.7 (e/γ very high) coinc abs conv (28B48, 52M51)	see Ga^{72}	daughter Ga^{72} (28B48); daughter As^{72} (14S50b)
Ge^{72}		27.37 (3I48a)					Ge^{72}, I = 0 (35T49)	
Ge^{73}		7.67 (3I48a)					Ge^{73}, I = 9/2 (35T49)	
Ge^{74}		36.74 (3I48a)					Ge^{74}, I = 0 (35T49)	
Ge^{75m}	A excit (9F52); cross bomb, n-capt, sep isotopes (91S52c)		IT (9F52)	42 s (9F52); 48 s (91S52c)	conv: 0.14 abs (9F52)	0.175 scint spect (91S52c); ~0.150 scint spect (24C52)		Ge^{74}-n-γ (91S52c); Ge-n-γ (9F52, 24C52); As-n-p (9F52, 91S52c)
Ge^{75}	A chem, excit, cross bomb (13S41a); n-capt, sep isotopes (22R50)		β^- (13S41a)	82 m (51M48); 89 m (13S41a); 79 m (22R50)	1.137 (85%, not coinc with γ), 0.614 (15%) spect (91S52c); 1.2 abs (13S41a); 1.3 abs (22R50)	0.265 (e/γ very small), 0.418, 0.572, other γ's spect, spect conv, scint spect (91S52c); 0.25 (~10%) (22R50); no γ (51M48)	Q_β^- 1.14 (91S52c)	Ge^{74}-n-γ (22R50, 91S52c); Ge-n-γ (42S39, 42S41, 2S47); Ge-d-p (42S39, 42S41, 13S41a); Ge-n-2n (42S41, 13S41a); Ge-γ-n (34H44, 12P49); As-n-p (42S41, 13S41a, 51M48); Se-n-α (42S41, 13S41a)
Ge^{76}		7.67 (3I48a)					Ge^{76}, I = 0 (35T49)	
Ge^{m}	E n-capt (24C52)		IT (24C52)	~0.35 s (24C52)		~0.06 scint spect (24C52)		Ge-n-γ (24C52)
Ge^{77m}	A cross bomb, genet, n-capt (23A47); sep isotopes (22R50)		β ~50%, IT ~50% calc (42F52); β^-, IT (14M52)	59 s (23A47); 57 s (22R50)	2.8 abs (23A47)	0.38 scint spect (14M52)	 (1/2-) Ge77m 0.38 (7/2+) Ge77 0 β- complex γ spectrum (3/2-) (91S52, HPS)	Ge-n-γ, parent As^{77} (23A47, 22R50); Ge^{76}-n-γ (22R50)
Ge^{77}	A chem, excit, cross bomb (13S41a)		β^- (42S41)	12 h (13S41a, 61S51, 22R50)	2.196 (42%, coinc with γ), 1.379 (35%), 0.71 (23%) spect (91S52); others (14M52, 61S51, 22R50, 26M49)	0.042, 0.073 (coinc with 0.213 and 0.264 γ), 0.213, 0.264, 0.368, 0.418, 0.564, 1.105, 1.75 spect, β-γ, γ-γ coinc (91S52); 0.209, 0.268, 0.300, 0.327, 0.366, 0.408, 0.425, 0.466 spect conv (91S52); 0.6, 0.3 (coinc with β^-) abs, β-γ coinc (22R50)	Q_β^- 2.46 (91S52)	Ge^{76}-n-γ (22R50); Ge-n-γ (42S39, 42S41, 2S47); Ge-d-p (42S41, 13S41a, 88S52); Se-n-α (13S41a); fission Th (21T51), U (61S46, 61S51), U^{233} (61S48); parent As^{77} (61S46, 61S51)

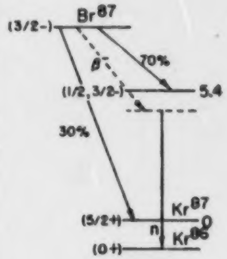
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{32}Ge^{78}$	B chem, genet (61S46, 61S51)		β^- (61S51)	2.1 h (61S51)	-0.9 abs (61S51)	γ (61S51)		fission U, parent As^{78} (61S51)
$_{33}As^{70}$	D chem (48H49, 48H50)		β^+ (48H50)	52 m (48H50)				As-d-p6n, daughter Se^{70} (48H50); not found: Ge^{70}-p (37A52)
As^{71}	A chem (42S41); chem, genet (48H49); mass spect (104B52)		EC (48H50); EC, β^+ (51M48a)	60 h (48H50); 50 h (51M48a)		0.162 spect conv (53M50)		Ga-α-2n (53M50); Ge-d-n (51M48a); As-d-p5n (48H50); parent Ge^{71} (48H49)
As^{72}	A chem, excit (14M47); chem, excit, sep isotopes (51M48a)		EC, β^+ (51M48a)	26 h (51M48a, 2V40); 27 h (48H50)	3.34 (19%), 2.50 (62%), 1.84 (12%), 0.67 (5%), 0.27 (2%) spect (53M50); 2.8 abs (14M47, 51M48a)	0.835, others up to 3.0 (weak) spect (53M50)	Q_β^+ 4.36 (53M50) see Ga^{72}  (53M50)	Ga-α-n (14M47, 51M48a, 53M50); Ge-p-n (2V40); As-d-p4n (48H50); Se^{74}-d-α (51M48a); daughter Se^{72} (48H48a)
As^{73}	A chem (42S39b); chem, excit, cross bomb, sep isotopes (51M48a); mass spect (17J51a)		EC (4E43b); no β^+ (4E43b, 51M48a)	76 d (51M48a); 90 d (42S39b, 53M50)		0.0135 (L/M 5.4), 0.0539 (K/L+M 5.6) spect conv, conv-conv coinc (17J51a, 17J52); 0.052 spect conv (4E43b, 53M50)	 (57W52)	Ge-d-n (42S39b, 4E43b); Ge^{70}-α-p (51M48a); Ge-α-p (51M48a, 53M50); As-d-p3n (48H50); Se^{76}-p-α (25F51)
As^{74}	A excit (48C38); chem, excit (42S39b)		β^- 53%, β^+ 47% (17J51); β^- ~67%, β^+ ~33% (53M50)	17.5 d (51M48a); 19.0 d (48H50); 16 d (42S39b)	β^-: 1.36 (51%), 0.69 (49%) spect (17J51); 1.45 (47%), 0.82 (53%) spect (53M50) β^+: 1.53 (11%), 0.92 (89%) spect (17J51); 0.96 spect (53M50)	γ_1 0.596, γ_2 0.635 (γ_1/γ_2 = 4) spect, β-γ coinc (17J51); 0.593 spect (53M50); 0.582 spect (20D41)	Q_β^- 1.36 (17J51) Q_β^+ 2.55 (17J51)  As^{74} 49% 51% β^- 11% 89% β^+ 0.635 (0+) 0 0.596 (0+) 0 (17J51)	Ga-α-n (51M48a); Ge-d-n (42S39b, 42S41, 2I42); Ge-p-n (2D40); As-n-2n (48C38, 42S39b); As-d-p2n (48H50); Se-d-α (23F40); Br-γ-αn (85H52); spall-fission Bi (11G49)

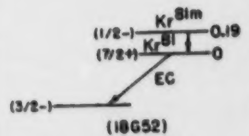
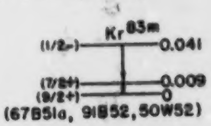
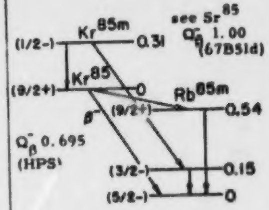
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation ≅ Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{33}As^{75}$		100 (6N37)					As^{75}, I = 3/2 (87M50, 29J52)	
As^{76}	A chem, n-capt (12A35)		β⁻, no β⁺: β⁺ lim 0.03% (63B47); β⁺ lim 0.07% (41M51); β⁺ lim 0.1% (16W48)	26.8 h (34W42); 26.3 h (14M40); 26.1 h (3P48)	3.04 (60%), 2.49 (25%), 1.29 (15%) spect (75S47d); 3.15 (54%), 2.57 (21%), 1.4 (19%), 0.4 (7%) spect (54M51); 3.15 (~40%), 2.7 (~30%), 1.1 (~30%) spect, β-γ coinc (3P48)	0.55, 1.20, 1.70 spect (75S47d); 0.557, 1.22, 1.78 (weak) spect (16W48); 0.558 (e_K/γ 0.002) spect conv (7T52); γ_1 0.57, γ_2 1.25, γ_3 1.84, γ_4 2.15 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 1/0.4/weak/weak) spect (43M46); 0.58, 1.20, 1.76, 2.02, no 2.3-2.7 γ (lim 0.01%) scint spect, γ-γ coinc (62B51); γ_1 0.555, γ_2 0.648, γ_3 1.210, γ_4 1.410, γ_5 2.06 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 1/0.1/0.25/0.02/0.06) spect (57H51); 0.568 (e/γ ~0), 1.25 (e/γ ~0) spect, spect conv (54M49, 54M51); others (52M51)	Q_β^- 3.1 (HPs)  (2-) As76 ~10% β⁻ ~20% ~20% ~50% 2.62 1.77 (2+) 0.56 (0+) 0 (HPS)	Ge-p-n (2V40); As-d-p (6T36, 48C38); As-n-γ (12A35, 48C38, 9O49, 50H51); Se-n-p (42S39b); Se-γ-p (42H47); Se-d-α (23F40); Br-n-α (48C38); Br-γ-αn, Br-γ-He³ (85H52)
As^{77}	A chem, genet (61S46, 61S51)		β⁻ (61S51)	38 h (18H50, 21T51); 40 h (61S51)	0.700 spect (43C51a); 0.679 spect (13J51); no conv (43C51a, 13J51)	no γ (43C51a, 13J51)	Q_β^- 0.70 (43C51a)  (3/2-) As77 β⁻ Se77m (7/2+) 0.162 (1/2-) 0 (43C51a, 18G52)	Br-γ-α (85H52); spall-fission Bi (11G49), Th (7N49a), U (6F51); fission Th (21T51), U (61S51) U^{233} (61S48); daughter Ge^{77} (61S51); daughter Ge^{77m} (23A47, 22R50); not parent Se^{77m} (lim 2%) (56M50a)
As^{78}	B chem (26S37a); excit (48C38)		β⁻ (26S37a)	90 m (61S51, 64B51); 80 m (48C38); 65 m (26S37a, 42S39b)	4.1 (~70%), 1.4 (~30%) abs (61S51); 1.4 cl ch (42S39b)	0.27 abs (42S39b); no γ coinc with 4.1 β⁻ (74S51a)	Q_β^- 4.1 (74S51a)	Br-n-α (26S37a, 48C38, 42S39b, 64B51); Br-γ-He³ (85H52); Se-n-p (42S39b); fission U, daughter Ge^{78} (61S46, 61S51)
As^{78}	F chem (64B51)			~40 m (64B51)				fission U, daughter (?) Ge^{78} (64B51)
As^{79}	D chem (65B50)		β⁻ (11V52)	9 m (65B50); 10 m (11V52)	~2.1 abs (11V52)			Se-γ-p (65B50); Se-n-pn (11V52)
$_{34}Se^{70}$	D chem (48H49, 48H50)		β⁺ (48H50)	~44 m (48H50)				As-d-7n, parent As^{70} (48H50)
Se^{72}	A chem, genet (48H48a)		EC (48H50)	9.7 d (48H50)				As-d-5n, parent As^{72} (48H48a, 48H50)

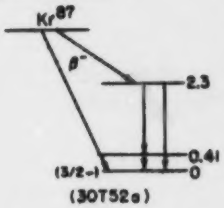
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$Se^{73(m?)}$	A chem (48H48a); chem, excit, sep isotopes (49C48)		β^+, EC, IT 20% (?) (62S51)	7.1 h (49C48, 62S51); 6.7 h (48H50)	1.68 (1%), 1.318 (88%), 0.750 (10%), 0.25 (1%) spect (62S51)	γ_1 0.0671 (conv in Se, K/L 7.6), γ_2 0.361 (K/L 8.6), γ_3 0.860, γ_4 1.310 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 10/163/11/8) spect, spect conv (62S51)	Q^+_β 2.70 (62S51)	Ge-α-n (49C48, 62S51); Ge^{70}-α-n (49C48); As-d-4n (48H50); spall-fission Bi (66B51)
Se^{74}		0.87 (24W48)					Se^{74}, I = 0 (55G50)	
Se^{75}	A chem, excit (2D40, 4K42); sep isotopes, n-capt (10C50)		EC, no β^+ (26F47, 49C48, 10C50)	127 d (49C48); 128 d (10C50); 115 d (26F47); 120 d (48H50)		γ_1 0.067, γ_2 0.077, γ_3 0.098 (K/L ~11, e/γ ~8), γ_4 0.124 (e/γ ~0.3), γ_5 0.138 (e/γ ~0.1), γ_6 0.203, γ_7 0.269 (e/γ ~0.09), γ_8 0.281, γ_9 0.308, γ_{10} 0.405 (e/γ ~0.001) ($\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_7/\gamma_8/\gamma_{10}$ = 0.14/~0.007/~0.02/0.21/0.70/~0.05/0.14) spect, spect conv, γ-γ coinc (13J52a); 0.025, 0.066, 0.081, 0.097, 0.121, 0.136, 0.199, 0.265, 0.280, 0.305, 0.402 spect conv (10C50); 0.076, 0.099 (?), 0.123, 0.137, 0.267, 0.283, 0.405 spect (11T48); 0.098 (e/γ large), all other γ (e/γ very small) spect, spect conv (75M51); others (52M51)	 Se^{75} EC 0.405 0.346 0.281 0.269 0.098 0.067 (3/2-) 0 (13J52a)	As-p-n (2D40); As-d-2n (4K42, 26F47, 49C48, 48H50); Se-n-γ (2S47, 26F47, 11T48, 13J52a); Se^{74}-n-γ (10C50)
Se^{76}		9.02 (24W48)					Se^{76}, I = 0 (55G50)	
Se^{77m}	A n-capt (23A47); sep isotopes, n-capt (18G48a); genet (43C51b)		IT (23A47)	17.5 s (23A47, 32G49, 43C51b)		0.162 (K/L 4.6) spect conv (31R52); 0.160 (e/γ large) spect, spect conv (43C51b); 0.165 spect conv (19C52); abs (9F50); others (38M51, 31K51, 32G49, 23A47)	see Br^{77}  (18G52)	Se-n-γ (23A47); Se^{76}-n-γ (18G48a); Se-x rays (32G49); daughter Br^{77} (43C51b, 43C51); not daughter As^{77} (lim 2%) (56M50a)
Se^{77}		7.58 (24W48)					Se^{77}, I = 1/2 (55G50, 32D51)	
Se^{78}		23.52 (24W48)					Se^{78}, I = 0 (55G50, 32D51)	

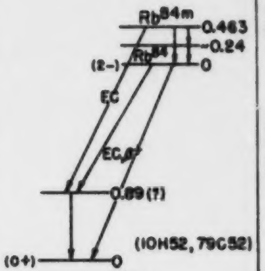
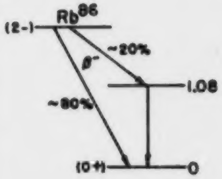
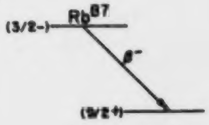
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{34}$Se^{79m}	A excit, n-capt (9F50, 9F50b); n-capt, sep isotopes (31R52)		IT (9F50b)	3.5 m (31R52); 3.9 m (9F50)		0.096 (K/L 2.9) spect conv (31R52)	 Se^{79m} (1/2-) 0.096 Se^{79} (7/2+) 0 β^- (3/2-) (18G52, HPS)	Se^{78}-n-γ (31R52); Se-n-γ, Se-n-2n (9F50, 9F50b); Br-n-p (9F50b)
Se^{79}	B chem, spect (?) (26P49)		β^- (26P49)	≤6.5 x 10^4 y sp act (est fission yield) (26P49)	0.160 abs (26P49); ~0.150 abs (32K50)	no γ (26P49)	Se^{79}, I = 7/2 (83H52)	fission U (26P49)
Se^{80}		49.82 (24W48)					Se^{80}, I = 0 (87M50)	
Se^{81m}	A chem, excit, cross bomb (26S37a); sep isotopes, n-capt (32L47); mass spect (67B49)		IT (20L40)	56.5 m (25W48); 57 m (26S37a, 20L40); 59 m (33G51)		0.103 (K/L 3.0) spect conv (31R52); 0.104 (e/γ very large, K/L ~3.9) spect conv (67B49); 0.099 (K/L ~4) spect conv (2H41)	 Se^{81m} (7/2+) 0.103 Se^{81} (1/2-) 0 β^- (3/2-)	Se-d-p (26S37a, 20L40); Se-n-γ (26S37a, 6H37, 2S47); Se^{80}-n-γ (32L47); Br-n-p (26S37a, 20L40); fission U (33G51); parent Se^{81} (20L40)
Se^{81}	A chem, genet (20L40)		β^- (20L40)	17 m (33G51); 18 m (9F50); 19 m (20L40); 13.6 m (25W48)	1.38 spect (67B49); 1.5 abs (20L40, 33G51); no conv (31R52)	no γ (33G51)	Q_β^- 1.38 (67B49, 33G51) (18G52)	Se-d-p (26S37a, 20L40); Se-n-γ (26S37a, 6H37, 2S47); Se-γ-n (37B39); Br-n-p (20L40); spall-fission Bi (66B51); fission U (33G51); daughter Se^{81m} (20L40)
Se^{82}		9.19 (24W48)					Se^{82}, I = 0 (55G50)	
Se^{83}	A chem, genet (23A47)		β^- (23A47)	67 s (23A47)	3.4 abs (23A47); no conv (31R52)			Se-n-γ (23A47); fission U (63S47); parent Br^{83} (23A47)
Se^{83}	A chem, excit, cross bomb (26S37a); chem, genet (20L40)		β^- (26S37a)	25 m (33G51a); 26 m (31R52); 30 m (20L40)	1.5 abs (33G51a, 31R52)	0.950, 0.176, 0.061 (?), 0.04 (?) spect conv, scint spect (31R52); 1.1, 0.37, 0.17 abs (33G51a)		Se-d-p (26S37a, 20L40); Se-n-γ (26S37a, 20L40, 2S47); fission Th (72B51), U (33G51a); parent Br^{83} (20L40, 33G51a)
Se^{84}	A chem, genet (33G46)		β^- (33G46)	~2 m (33G51b, 20E51)				fission U, parent Br^{84} (33G51b, 20E51)
$_{35}$Br^{74}	D chem (13H51)		β^+, EC (13H51)	~35 m (13H51)				Cu-C-3n (13H51)
Br^{75}	B chem, cross bomb, sep isotopes (35W48)		β^+, EC (35W48)	1.6 h (13H51); 1.7 h (35W48)	1.70 (46%), 0.8 (20%), 0.6 (15%), 0.3 (19%) spect (25F52); ~1.8 abs (13H51)	~0.6 abs (25F52)		Cu-C-2n (13H51); Se^{74}-d-n (35W48); Se^{74}-p-γ (35W48, 25F52)
Br^{76}	A chem (48H48); chem, excit (13H51); chem, sep isotopes (25F52)		β^+ (48H48)	17.2 h (25F52); 16.5 h (13H51); 15.7 h (48H48)	3.57 (46%), 1.7 (10%), 1.1 (11%), 0.8 (14%), 0.6 (19%) spect (25F52); 3.5 spect (13H51)	1.2, 0.96, 0.75, 0.68, 0.42, 0.37, 0.33, 0.25 spect, spect conv (25F52); ~2 abs (48H48)	Q_β^+ 4.6 (25F52)	As-α-3n (48H48, 13H51); Se^{76}-p-n (25F52)

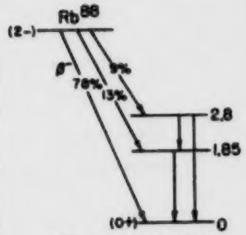
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{35}Br^{77}$	A chem, sep isotopes (35W48)		EC 95%, β^+ 5% (35W48)	57 h (48H48, 13H51); 58 h (35W48)	0.336 spect (43C51); 0.36 spect (48H48); abs, spect (35W48)	γ_1 0.160, γ_2 0.237, γ_3 0.284, γ_4 0.298, γ_5 0.520, γ_6 0.641, γ_7 0.813 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7$ = 0.6/20/0.2/0.2/100/8.6/25) spect, spect conv (43C51); 0.160, 0.234, 0.299, 0.521 spect conv, x-γ coinc (25F52)	see As^{77}  Br77 EC β+ 0.813 0.520 0.237 0.160 0 Se77m (1/2-) (43C51)	As-α-2n (48H48, 13H51, 43C51); Se^{74}-α-p (35W48): Se^{76}-d-n (35W48, 25F52); parent Se^{77m} (43C51, 43C51b)
Br^{78}	A chem, excit (26S37a)		β^+ (26S37a)	6.4 m (26S37a); 6.5 m (13H51)	2.4 abs (35B46a, calc from 26S37a); 2.3 abs (26S37a)	0.108, 0.046 spect conv (6V39)		As-α-n (26S37a, 13H51); Se-d-n (26S37a); Se-p-n (59B38, 6V39); Br-γ-n (7C37, 37B39); Br-n-2n (6H37)
Br^{79}		50.52 (9W46)					Br^{79}, I = 3/2 (87M50)	
Br^{80m}	A chem, n-capt (12A35); chem, excit, cross bomb (26S37a)		IT (24S39)	4.58 h (41M51); 4.5 h (26S37a); 4.4 h (59B38)		0.049 0.037 (e/γ -1.3) ion ch (32[illegible]50); 0.048, 0.036 spect conv (33L50); 0.049, 0.037 spect conv (6V39); 0.049 (L_I/L_{III} 1.0) spect conv (63M52a); 0.048 (e/γ very large), 0.037 (e/γ ~1) abs (35G40); others (52W51)		Se-d-2n (35W48, 25F52); Se-α-p (35W48); Se-p-n (59B38, 6V39, 25F52); Br-n-γ (24A36, 26S37a, 24S39, 34G46, 2S47); Br-d-p (26S37a); Br-γ-n (37B39); Br-n-2n (1P37); spall-fission Ta (22N52), Bi (66B51), U (6F51); fission Th (?) (9P40, 9P41)
Br^{80}	A chem, n-capt (12A35); chem, excit, cross bomb (26S37a); chem, genet (24S39)		β^- ~92%, β^+ ~3%, EC ~5% (calc from 41M51, 28R50); β^+/β^- 0.037 (41M51); $\frac{\beta^+ + EC}{\beta^-}$ 0.09 (28R50); β^+/β^- 0.028 (34L51); β^+/β^- 0.03 (63B47)	18 m (26S37a, 24S39)	β^-: 1.99 (85%), 1.1 (15%) spect (34L52); 1.97 (80%), 1.1 (11%), 0.7 (9%) spect (25F52); 1.99 spect (33L50); others (34L51, 50C48, 24A36) β^+: 0.87 spect (34L51); 1.0 spect (16D49); 0.73 abs (63B47)	>0.6 abs (21D40); <0.5 abs (26S37a, 59B38); no γ (34L52)	Q_β^- 2.0 (25F52)  Br80m (5-) 0.086 (2-) 0.037 Br80 (1+) 0 EC β+ β- 0.9 (0+) (0+) 0 (18G52, HPS)	Se-p-n (59B38); Br-n-γ (26S37a, 34G46, 2S47, 9O49); Br-d-p (26S37a); Br-γ-n (37B39); Br-n-2n (1P37); daughter Br^{80m} (24S39, 21D40, 64S41)
Br^{81}		49.48 (9W46)					Br^{81}, I = 3/2 (87M50)	
Br^{82}	A chem, n-capt (33K35); chem, excit, cross bomb (26S37a)		β^- (33K35); no EC or β^+ (lim 0.03%) (28R50); no β^+ (lim 0.02%) (41M51)	35.87 h (31C50); 36.0 h (68B50); 35.1 h (36W51); 35.7 h (38S51)	0.465 spect, β-γ coinc (33R41, 20D42b)	γ_1 0.547, γ_2 0.608, γ_3 0.692, γ_4 0.766, γ_5 0.823, γ_6 1.031, γ_7 1.312 spect conv, spect (7S49a); γ_1 0.535, γ_2 0.602, γ_4 0.750, γ_6 1.020, γ_7 1.292, γ_8 1.445 ($\gamma_1/\gamma_4/\gamma_6/\gamma_7/\gamma_8$ = 3.7/3.5/1.0/0.85/0.40) spect (16D52); 0.547, 0.615, 0.682, 0.752, 0.822, 1.026, 1.306, 1.453 spect (57H51a); 1.7-2.0 (0.14%) Be-γ-n reaction (33M49); 0.07, 0.05 abs conv (69B44); others (52M51)		Se-p-n (59B38, 6R41a); Se-d-2n (26S37a, 56M51); Br-n-γ (33K35, 26S37a, 2S47); Br-d-p (26S37a, 56M51); Rb-n-α (26S37a); spall-fission Ta (22N52), Hg (63S52), Tl (2T47b), Pb (13P47a), Bi (66B51, 13P47, 11G49), U (6O48, 6F51); fission U (2F51)

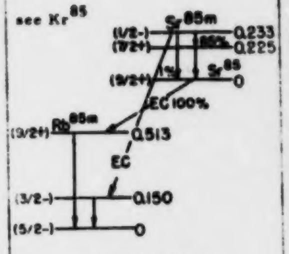
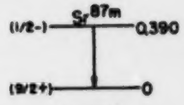
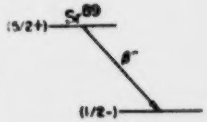
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{35}$Br^{83}	A chem, excit (26S37a)		β^- (26S37a)	2.33 h (20L40, 49H51a); 2.4 h (33G51a, 26S37a)	0.940 spect (23D51); 0.94 spect (25F52)	no γ (26S37a, 33G51a); ~0.046 (?) cl ch (50W52)		Se-d-n (26S37a, 25F52); Rb-γ-α (49H51a); spall-fission Ta (22N52), Hg (63S52), Pb (13P47a), Bi (13P47, 11G49, 66B51), Th (7N49a), U (6O48); fission Th (6B39, 20L40, 21T51, 72B51), U (20L40, 65S40, 57M41, 33G51a), U^{233} (61S48), Pu (32K48, 61S51a); daughter Se^{83}, parent Kr^{83m} (20L40, 65S40, 57M41, 33G51a)
Br^{84}	A chem (22D39); chem, excit (70B43)		β^- (22D39)	30 m (65S40); 32 m (23D51); 33 m (32K51)	4.68 (40%), 3.56 (9%), 2.53 (16%), 1.72 (35%) spect (23D51)	0.89, 1.89 scint spect (10L52d)		Rb-n-α (70B43); spall-fission Bi (13P47a), U (6F51); fission Th (72B51), U (22D39, 16H39a, 16H39b 65S40, 57M41, 70B43, 32K51); daughter Se^{84} (33G51b)
Br^{85}	A chem (65S40); chem, genet (66S43)		β^- (65S40)	3.00 m (63S49); 3.0 m (65S40, 70B43)	2.5 abs (63S49)	no γ (63S49)		fission U (65S40, 70B43, 66S43, 63S49); parent Kr^{85} (66S43, 63S49)
Br^{87}	A chem (65S40, 26S47); chem, genet (70B43, 63S49)		β^-, β^-n (~2% of disintegrations) (19L51a)	55.6 s (n) (28H48a); 55.0 s (n) (34R47); 56.1 s (β^-) (63S49)	β^-: 2.6 (70%), 8.0 (30%) abs (67S51); n (mean): 0.25 abs paraffin (28H48a); 0.30 p recoil in cl ch (71B46)	5.4, others ~3 abs, abs sec, γ-γ coinc (67S51)	Q_{β}^{-} ~8 (?) (67S51)  Br87 (3/2-) β⁻ 70% (1/2, 3/2-) 5.4 30% Kr87 (5/2+) 0 n Kr86 (0+) (67S51)	fission U (65S40, 26S47, 63S47a, 63S49), U^{235} (34R47, 28H48a), Pu (34R47); parent Kr^{87} (70B43, 66S43, 63S49); parent Kr^{86} (2% of dis) (26S47, 63S49)
Br^{88}	A chem, genet (63S49)		β^- (63S49)	15.5 s (63S49)				fission U, parent Kr^{88} (63S49)
Br^{89}	D chem (63S47a)		β^-, β^-n (26S47a, 28H48a)	4.51 s (n) (28H48a); 4.45 s (n) (34R47)	n (mean): 0.43 abs paraffin (28H48a); 0.65 p recoil in cl ch (71B46)			fission U (63S47a, 26S47a, 63S49), U^{235} (34R47, 28H48a); parent Kr^{89} (?), parent Kr^{88}(?) (51C51)
$_{36}$Kr^{77}	B chem, sep isotopes (35W48a)		EC 70%, β^+ 30% (35W48a)	1.1 h (35W48a)	1.7 abs (35W48a)	γ (35W48a)		Se-α-n, Se^{74}-α-n (35W48a)
Kr^{78}		0.354 (6N50a)						

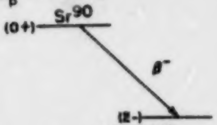
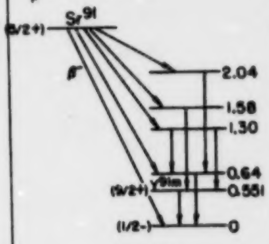
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{36}Kr^{79m}$	D chem (29C40b)		IT (?), no β^+ (29C40b)	55 s (29C40b)		0.127 spect conv (29C40b)		Br-p-n (33B40a, 29C40b)
Kr^{79}	A chem (29C40b); chem, sep isotopes (35W48a); mass spect (104B52)		EC 95% (L/K 0.27), β^+ 5% (12R52a, 12R52b); EC (K) ~90%, β^+ ~10% (67B51); EC ~98%, β^+ ~2% (35W48a)	34.5 h (12R52); 34 h (33B40a, 35W48a, 29C40b)	0.595 spect (67B51); 0.6 abs (58H51)	0.263 (e/γ ~0.02), 0.044 spect conv (67B51); 0.2 abs (58H51)		Se-α-n (52C41); Se^{76}-α-n (35W48a); Br-d-2n (30C44); Br-p-n (33B40a, 29C40b); Kr-d-p (26S37a, 52C41); Kr-n-γ (58H51, 67B51)
Kr^{80}		2.27 (6N50a)						
Kr^{81m}	A chem (29C40b); genet (7K50)		IT, no β^+ (29C40b)	13 s (29C40b); ~10 s (7K50)		0.193 spect conv (7K50); 0.187 spect conv (29C40b)	 (18G52)	Br-p-n (33B40a, 29C40b); daughter Rb^{81} (7K50)
Kr^{81}	A chem, mass spect (28R50a)		EC (28R50a)	2.1 x 10^5 y sp act (28R50a)		0.012 abs, Br K-x (28R50a)		Kr-n-γ (28R50a)
Kr^{82}		11.56 (6N50a)					Kr^{82}, I = 0 (87M50)	
Kr^{83m}	A chem, genet (20L40); mass spect (67B50)		IT (20L40)	114 m (67B51a, 21R46); 113 m (20L40)		0.0322 (e/γ very large, K/L+M 0.35), 0.0093 (e/γ very large, L/M ~3) spect conv (67B51a); 0.032 (K/L 0.32), 0.009 (e/γ ~10) ion ch (91B52); 0.046, 0.029 spect conv (2H41)	 (67B51a, 91B52, 50W52)	Se-α-n (52C41); Kr-d-p (52C41); Kr-n-γ, Kr-x rays (37W45); fission U, daughter Br^{83} (20L40); daughter Rb^{83} (53C50)
Kr^{83}		11.55 (6N50a)					Kr^{83}, I = 9/2 (87M50)	fission U (mass spect) (13T47, 13T48a)
Kr^{84}		56.90 (6N50a)					Kr^{84}, I = 0 (87M50)	fission U (mass spect) (13T47, 13T48a)
Kr^{85m}	A chem (26S37a); chem, mass spect (34K49)		β^- 77%, IT 23% (67B51d)	4.36 h (34K49); 4.4 h (35W48a); 4.5 h (58H51, 26S37a); 4.6 h (21R46, 66S43)	0.855 spect (67B51d); 0.85 abs (70B43a); 0.95 abs (58H51); 0.75 abs (34K49)	0.150 (e/γ 0.057, coinc with β^-), 0.305 spect conv, β-γ coinc (67B50a, 67B51d); 0.17, 0.37 abs (58H51)	see Sr^{85} Q_β^- 1.00 (67B51d) 	Se-α-n (35W48a); Kr-d-p (26S37a, 52C41); Kr-n-γ (21R45, 58H51); Rb-n-p, Sr-n-α (70B43); fission U, daughter Br^{85} (66S43, 63S49)
Kr^{85}	A chem (58H51a); chem, mass spect (13T47)		β^- (58H51a)	9.4 y (13T48a); ~10 y (58H51a)	0.695 (99+%), 0.15 (0.65%) spect, β-γ coinc abs (8Z50); 0.74 abs (58H51a)	0.54 (coinc with 0.15 β^-) scint spect, abs, β-γ coinc (8Z50)	Q_β^- 0.695 (HPS) (8Z50, 67B50a, 18G52)	Kr-n-γ (58H51); fission U (13T47, 58H51a)
Kr^{86}		17.37 (6N50a)					Kr^{86}, I = 0 (87M50)	fission U (mass spect) (13T47, 13T48a); daughter Br^{87} (2% of dis) (26S47, 63S49)

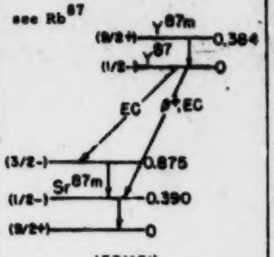
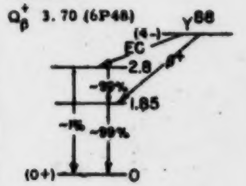
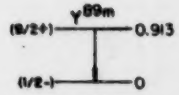
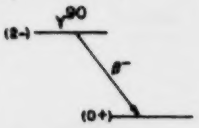
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{36}Kr^{87}$	A chem (26S37a); chem, mass spect (34K49)		β^- (26S37a)	78 m (34K49); 75 m (66S43, 63S49); 74 m (26S37a)	3.63 (75%), 1.27 (25%) spect (30T52a); others (34K49, 70B43a)	0.41, 1.89, -2.3 scint spect (30T52a)	Q_{β}^- 3.6 (30T52a)  (30T52a)	Kr-n-γ (21R46, 58H51); Kr-d-p (26S37a); Rb-n-p (70B43); fission U (70B43, 66S43); daughter Br^{87} (66S43, 70B43, 63S49)
Kr^{88}	A chem (6H39); chem, genet (20L39); chem, mass spect (34K49)		β^- (20L39)	2.77 h (34K49); 2.8 h (36G40, 63S49)	2.8 (20%), 0.9 (12%), 0.52 (68%) spect (30T52b); 2.4 (weak), -0.5 abs (4J48, 34K49)	0.028 (coinc with 0.5 β^-, e/γ -0.1, K/L+M 8) spect conv, β-γ coinc (30T52b)		fission Th (20L39, 25A39), U (6H39, 16H40a, 36G40, 16H40b); parent Rb^{88} (20L39, 25A39, 6H39, 16H40a, 36G40, 16H40b); daughter Br^{88} (63S49)
Kr^{89}	A chem, genet (36G40, 66S40); mass spect (35K51a)		β^- (36G40)	3.18 m (35K51a); 2.6 m (24D51); 2.5 m (16H43a)	4.0 abs (35K51a); 3.9 calc from average recoil energy (35K51)			fission U, parent Rb^{89} (36G40, 66S40, 16H40b, 16H43, 17B51, 35K51a); spall-fission U (11O51); fission Pu (26A51)
Kr^{90}	A chem, genet (24D51a); mass spect (35K51a)		β^- (24D51a)	33 s (35K51a, 32K46)	3.2 abs (35K51a)			fission U, ancestor Sr^{90} (24D51a, 24D51); fission Pu (26A51); parent Rb^{90} (35K51a)
Kr^{91}	A chem, genet (16H40c); mass spect (35K51a)		β^- (16H40c)	9.8 s (24D51); 10 s (35K51a); -6 s (11O51)	-3.6 abs (35K51a)			fission U, ancestor Y^{91} (16H40c, 17B51, 24D51a, 24D51); spall-fission U (11O51): fission Pu (26A51) parent Rb^{91}, parent Rb^{91m} (35K51a)
Kr^{92}	B chem, genet (16H40a, 24D51)		β^- (16H40a)	3.0 s (24D51)				fission Th (16H40), U (16H40a, 16H40b, 16H43), Pu (26A51); ancestor Y^{92} (24D51)
Kr^{93}	B chem, genet (16H42, 70S51)		β^- (16H42)	2.0 s (24D51)				fission U, ancestor Y^{93} (70S51); spall-fission U (11O51); fission Pu (26A51)
Kr^{94}	B chem, genet (16H43a, 24D51)		β^- (16H43a)	1.4 s (24D51)				fission U, ancestor Y^{94} (16H43a, 24D51)
Kr^{95}	A chem, genet (24D51a)		β^- (24D51a)	short (24D51a)				fission U, ancestor Zr^{95} (24D51a)
Kr^{97}	B chem, genet (26A51)		β^- (26A51)	-1 s (24D51)				fission U, ancestor Zr^{97} (26A51, 24D51); fission Pu (26A51)
$_{37}Rb^{81}$	A chem, mass spect (10R49)		EC 87%, β^+ 13% (7K50)	4.7 h (7K50)	0.990 spect (7K50)	0.95 abs (7K50)		Br-a-2n (10R49, 7K50); parent Kr^{81} (7K50)
Rb^{82m}	B chem, genet (54L52)		β^+ (54L52)	1.25 m (54L52)	-3 abs (54L52); see Sr^{82}			daughter Sr^{82} (54L52)
Rb^{82}	A chem (59H40); chem, mass spect (10R49)		EC 94%, β^+ 6% (7K50)	6.3 h (7K50)	0.775 (76%), 0.175 (24%) spect (10H52); 0.670 spect (7K50)	0.188, 0.248, 0.322, 0.390, 0.423, 0.465, 0.558, 0.610, 0.690, 0.768, 0.818, 1.020, 1.314, 1.464 spect conv, spect (10H52)		Br-a-n (59H40, 10R49, 7K50); Kr-d-2n (59H40); not daughter Sr^{82} (lim 0.01%) (54L52)

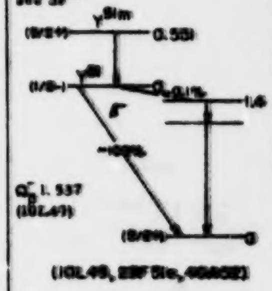
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{37}Rb^{83}$	A chem, mass spect (7K50)		EC (7K50)	83 d (53C50); 107 d (7K50)		-0.45, -0.15 spect conv (53C50)		Br-a-2n (7K50); daughter Sr^{83} (53C50); parent Kr^{83m} (53C50)
Rb^{84m}	B chem (59H40); chem, excit (9F50a)		IT, EC (weak) (79C52); EC (9F50a)	23 m (9F50a); 20 m (59H40)		γ_1 0.463 (not coinc with γ_2 or γ_3), γ_2 0.239, γ_3 -0.239 (coinc with γ_2), γ_4 0.890 (γ_1/γ_4 = 7) scint spect, γ-γ coinc (79C52)	 Rb^{84m} 0.463 -0.24 Rb^{84} (2-) 0 EC EC,β^+ 0.89 (?) (0+) 0 (10H52, 79C52)	Br-a-n (59H40); Rb-n-2n (9F50a, 79C52)
Rb^{84}	A chem, cross bomb (63B47); chem, mass spect (7K50)		EC, β^+, β^- (?) (7K50, 73B50); EC/β^+ -13 (7K50); β^+/β^- -6.2 (73B50)	34 d (7K50); 38 d (73B50)	β^+: 1.629 (39%), 0.822 (58%), 0.373 (?) (3%) spect (10H52); 1.5 spect (7K50); 1.3 abs (73B50)	0.890 scint spect, spect conv (10H52); 0.85 abs (7K50); 0.8 abs (73B50)		Br-a-n (7K50, 73B50); Kr-a-pn, Kr-d-2n (73B50); Rb-n-2n (63B47); Sr-d-a (63B47)
Rb^{85m}	A genet (14S52)		IT (14S52)	0.9 x 10^{-6} s delay coinc (14S52)		0.513 spect, spect conv (11T51, 14S52)	see Sr^{85} and Kr^{85}	daughter Sr^{85} (14S52)
Rb^{85}		72.15 (6N50a)					Rb^{85}, I = 5/2 (87M50)	fission U (mass spect) (38W52)
Rb^{86m}	B chem, excit, n-capt (9F51)		IT, no EC (12P52); EC (9F51)	0.99 m (12P52); 1.06 m (9F51)		0.57 scint spect (12P52); 0.78 abs (9F51)		Rb-n-γ, Rb-n-2n (9F51)
Rb^{86}	A chem, n-capt (26S37a); chem, excit (2H41a)		β^- (2H41a); no β^+ (lim 0.002%) (41M51); no EC (lim 0.04%) (12P52)	19.5 d (2H41a)	β_1 1.82 (80%), β_2 0.72 (20%) spect (5Z48); β_1 1.79 spect (96M52); β_1 1.76, β_2 0.670 (coinc with γ) β-γ coinc spect (23M51); β_1 1.82 (~67%), β_2 0.56 (~33%) abs (15J48); β_2 0.72 (coinc with γ) β-γ coinc spect (55M50); β_2 0.67 scint spect (27P51); β_2 (12%) β-γ coinc (26M50)	1.076 spect (55M50); 1.081 spect (5Z48); 1.12 (coinc with β_2) coinc abs sec, β-γ coinc (15J48); others (85S51)	Rb^{86}, I = 2 (98B51) Q_β^- 1.8 (5Z48)  Rb^{86} (2-) ~20% β^- 1.08 ~80% (0+) 0 (5Z48, HPS)	Rb-n-γ (26S37a, 69S38, 2S47); Rb-γ-n (34H44); Sr-d-a (2H41a); spall-fission Bi (11G49, 66B51), U (6F51); fission U (2F51a)
Rb^{87}	A chem (1T05, 54C06); chem, genet (16H37a, 8M37); chem, mass spect (40H37)	27.85 (6N50a)	β^- (1T05, 54C06)	6.0 x 10^{10} y sp act (37H48, 37H48a, 37K49, 50L52); 6.4 x 10^{10} y sp act (79M52); 6.2 x 10^{10} y sp act (21C51); 7.6 x 10^{10} y (55C51, calc from 21C51); 6.3 x 10^{10} y yield (65S38); 5.8 x 10^{10} y sp act (10E46)	0.275 spect (21C51); scint spect (50L52); 0.270 scint spect (11B50e); others (36K35, 34T52, 3L39, 14O41, 12S46)	no γ (21C51, 79M52, 50L52)	Rb^{87}, I = 3/2 (87M50) Q_β^- 0.27 (21C51)  (21C51, 79M52)	natural source (1T05, 54C06); fission U (mass spect) (38W52); parent Sr^{87} (mass spect) (16H37a, 8M37)

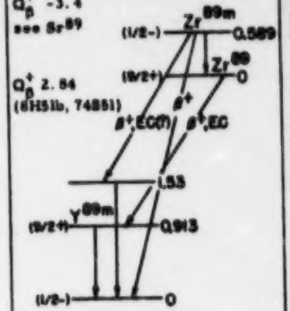
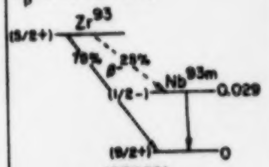
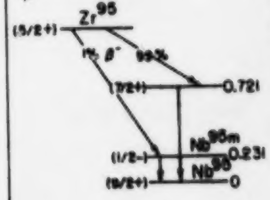
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{37}Rb^{88}$	A chem (26S37a); chem, genet (20L39, 36G40, 16H39a)		β^- (16H39a)	17. 8 m (36G40, 2B51); 17. 7 m (30T52b); 17. 5 m (34W42); 18 m (16H40b, 26S37a)	5. 30 (78%), 3. 6 (13%), 2. 5 (9%) spect (30T52b); 5. 13 (66%), 3. 29 (19%), 2. 0 (15%) spect (2B51); 5. 20 (~66%), 3. 6 (~17%), 1. 8 (~17%) abs (37G51)	2. 8, 1. 86, 0. 90 spect (2B51); γ_1 3. 0, γ_2 1. 7 ($\gamma_1/\gamma_2 \sim 1/10$) abs sec, β-γ coinc (37G51)	see Y^{88} Q_β^- 5. 30 (30T52b)  Rb88 (2-) β^- 78% 13% 9% 2.8 1.85 (0+) 0 (2B51, 30T52b, HPS)	Rb-n-γ (26S37a, 1P37, 69S38, 2S47); fission Th (25A39), Pa (2G39); fission U, daughter Kr^{88} (6H39, 20L39, 36G40, 16H40a, 16H40b)
Rb^{89}	A chem, genet (36G40, 66S40)		β^- (36G40)	15. 4 m (36G40); 15. 5 m (16H40b)	4. 5 abs (35L46a, calc from 36G40); 3. 8 abs (36G40)	γ (35B46a)		fission U, daughter Kr^{89} (36G40, 66S40, 16H40b, 16H43, 17B51); parent Sr^{89} (36G40, 16H40a, 16H40b, 16H43)
Rb^{90}	A chem, genet (35K51a)		β^- (35K51a)	2. 74 m (35K51a)	5. 7 abs (35K51a)	γ (35K51a)		fission U, daughter Kr^{90}, parent Sr^{90} (24D51a, 24D51, 35K51a)
Rb^{91}	A chem, genet (35K51a)		β^- (35K51a)	1. 67 m (35K51a); [short] (24D51a, 17B51, 11O51, 24D51, 16H40c)	4. 6 abs (35K51a)	γ (35K51a)		fission U, daughter Kr^{91}, parent Sr^{91} (35K51a); ancestor Y^{91} (24D51a, 16H40c)
Rb^{91}	A chem, genet (35K51a)		β^- (35K51a)	14 m (35K51a)	3. 0 abs (35K51a)	γ (35K51a)		fission U, daughter Kr^{91}, parent Sr^{91} (35K51a)
Rb^{92}	D chem, genet (16H40a)		β^- (16H40a)	80 s (16H40a); [short] (17B51, 24D51)				fission U, daughter Kr^{92} (24D51); ancestor Y^{92} (16H40a, 16H40c, 16H40, 16H43, 24D51)
Rb^{93}	[B] genet (16H42, 17B51)		[β^-] (16H42)	[short] (17B51, 24D51, 24D51a, 16H42, 16H43)				fission U, daughter Kr^{93} (17B51, 24D51, 24D51a); ancestor Y^{93} (16H42, 16H43, 17B51)
Rb^{94}	[B] genet (16H43, 16H43a)		[β^-] (16H43, 16H43a)	[short] (24D51, 16H43, 16H43a)				fission U, daughter Kr^{94}, ancestor Y^{94} (16H43, 16H43a, 24D51)
Rb^{95}	[A] genet (24D51a)		[β^-] (24D51a)	[short] (24D51a)				fission U, daughter Kr^{95}, ancestor Zr^{95} (24D51a)
Rb^{97}	[A] genet (24D51)		[β^-] (24D51)	[short] (24D51)				fission U, daughter Kr^{97}, ancestor Zr^{97} (24D51); fission U^{235}, Pu (26A51)

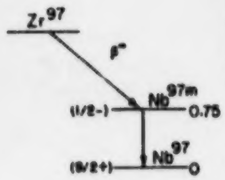
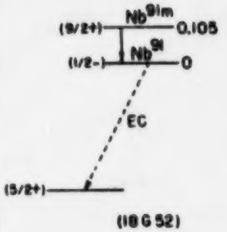
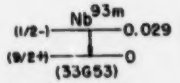
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{38}Sr^{81}$	B chem, genet (53C50)		EC, β^+ (53C50)	29 m (53C50)	conv (53C50)			spall Rb, parent Rb^{81} (53C50)
Sr^{82}	A chem, excit (53C50); mass spect (97M52)		EC, β^+ (?) (53C50)	27 d (97M52); 25 d (53C50)	β^+ with Rb^{82m} (54L52); 3.15 spect (53C50)	0.95, -0.40, -0.15 spect conv, abs (53C50)		spall Rb (53C50); daughter Y^{82} (78C52); parent Rb^{82m}, not parent Rb^{82} (lim 0.01%) (54L52)
Sr^{83}	A chem, genet (53C50); mass spect (97M52)		EC, β^+ (53C50)	33 h (97M52); 38 h (53C50)	1.15 spect (53C50); 1.35 abs (97M52)	0.040, 0.074, 0.101, 0.151, 0.165 spect conv (53C50)		spall Rb, parent Rb^{83} (53C50); daughter Y^{83} (78C52)
Sr^{84}		0.56 (6N38b)						
Sr^{85m}	A chem, excit (2D40a)		IT 86%, EC 14% (14S52)	70 m (2D40a)		0.0075 (e/γ very large), 0.150 (with EC), 0.225 (e/γ 0.031, K/L ~5.5), 0.233 (e/γ ~0.04) scint spect, spect conv, x-γ coinc (14S52); 0.233, 0.152 spect conv (11T51)	see Kr^{85}  Sr^{85m} (1/2-) (7/2+) 0.233 0.225 86% 1% Sr^{85} (9/2+) 0 EC 100% Rb^{85m} (9/2+) 0.513 EC (3/2-) 0.150 (5/2-) 0 (14S52, 18G52)	Rb-p-n (2D40a); Rb-d-2n (11T51); Sr^{84}-n-γ (14S52)
Sr^{85}	A chem, excit (2D40a)		EC (35L51, 11T51); no β^+ (11T51)	65 d (11T51); 66 d (2D40a)		with Rb^{85m}: 0.513 spect, spect conv (11T51) 0.513 (~100%, e/γ 0.008) spect conv, x-γ coinc, scint spect (14S52); 0.514 (~100%, e/γ 0.007, K/L ~12) spect, spect conv, coinc abs (2E52)		Rb-p-n (2D40a); Rb-d-2n (11T51, 35L51, 2E52); parent Rb^{85m} (14S52); daughter Y^{85} (78C52)
Sr^{86}		9.86 (6N38b)					Sr^{86}, I = 0 (87M50)	
Sr^{87m}	A chem, excit (71S37); chem, excit, cross bomb, genet (2D40a)		IT (2D40a)	2.80 h (58M51, 8H51b); 2.75 h (2D40a)		0.388 (K/L+M 5.79) spect conv (59G52); 0.390 (e/γ 0.28, K/L+M 6.9) spect conv, x-conv coinc (58M51); 0.388 (K/L+M 5.5) spect conv (79B52); 0.388 spect conv (11T51); 0.394 (K/L 7.2) spect conv (8H51b); 0.386 spect conv (2H41)	 (18G52)	Rb-p-n (2D39); Sr-n-n (2D40a, 35R40, 35R40a); Sr-x rays, Sr-e-e (37W45a); Sr-d-p (71S37); Sr-n-γ (71S37, 2D39, 35R40, 2S47, 2S47a); Sr-p-p (?) (2D40a); daughter Y^{87} (2D39, 2D40a, 58M50, 18H51b, 58M51); Zr-n-α (42S40)
Sr^{87}		7.02 (6N38b)					Sr^{87}, I = 9/2 (87M50)	
Sr^{88}		82.56 (6N38b)					Sr^{88}, I = 0 (87M50)	
Sr^{89}	A chem, excit (71S37); chem, mass spect (60H48)		β^- (71S37)	53 d (1N51); 54 d (36L39); 55 d (71S39, 11G49)	1.463 spect (10L49); 1.48 spect (17N44); 1.5 spect (72S49, 4W44, 11R47); cl ch (71S39)	no γ (1N51, 71S39, 71S37); others (52M51)	see Zr^{89} Q_{β}^{-} 1.46 (10L49)  (18G52)	Sr-d-p (71S37, 71S39); Sr-n-γ (71S37, 71S39, 2S47); Y-n-p (42S38); Zr-n-α (?) (42S40); spall-fission Pt (2T47b), Pb (13P47a), Bi (2T47b, 11G49, 66B51), Th (7N49a), U (6O48, 11O51, 6F51); fission Th (72B51, 21T51), U^{233} (38G48, 61S48), U^{235} (38G46), Pu (28F51); fission U, daughter Rb^{89} (36G40, 16H40a, 16H40b, 16H43, 38G46)

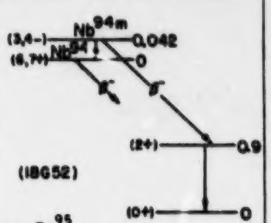
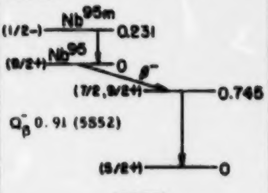
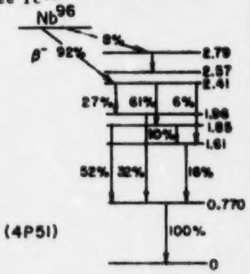
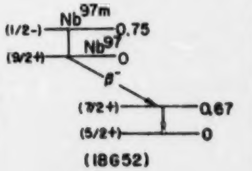
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
Sr^{90}	A chem, genet (16H42); chem, mass spect (60H48, 38W52)		β^- (18N51)	19.9 y (28P50)	0.61 spect (47M48a); 0.54 spect (23L50); 0.53 spect (74B49); 0.6 abs (38G46, 33G51c)	no γ (33G51c, 39G43)	Q_β^- 0.6 (HPS)  (74B49)	spall-fission Bi (11G49), Th (7N49a); fission Th (21T51), U^{233} (38G48), U^{235} (38G46); fission U, daughter Rb^{90} (24D51a, 24D51, 35K51a, 38W52); parent Y^{90} (16H42, 16H43, 38G46, 18N51)
Sr^{91}	A chem, genet (40G41); chem, excit (66S43a)		β^- (40G41)	9.7 h (28F51a); 10 h (16H43)	2.665 (26%), 2.03 (4%), 1.36 (29%), 1.09 (33%), 0.62 (7%) spect (40A52); 3.2 (~60%), 1.3 (~40%) abs (28F51a)	0.551 (with Y^{91m}, K/L+M 6.0), 0.64, 0.66, 0.747, 1.025, 1.413 (coinc with 0.630 γ) spect, scint spect, γ-γ coinc (40A52)	Q_β^- 2.66 (40A52)  Sr^{91} (5/2+) β^- 2.04 1.58 1.30 0.64 0.551 Y^{91m} (9/2+) (1/2-) 0 (40A52)	Zr-n-a (66S43a); spall-fission Pt (2T47b), Hg (π^-) (63S52), Pb (13P47a), Bi (13P47a, 13P47, 66B51), Th (7N49a), U (6F51), U (C) (13H51); fission Th (72B51, 21T51), Pu (32K48, 28F51); fission U, parent Y^{91m}, parent Y^{91} (40G41, 16H43, 28F51a); daughter 1.7 m Rb^{91}, 14 m Rb^{91} (35K51a)
Sr^{92}	B chem, genet (40G41)		β^- (40G41)	2.7 h (40G41)				spall-fission Th (7N49a); fission Th (72B51), U (16H40a, 16H43, 16H43a, 32K51a, 17B51), Pu (32K48); parent Y^{92} (40G41, 58H51b)
Sr^{93}	B chem (36L39); chem, genet (16H43)		β^- (36L39)	7 m (36L39)				fission U (36L39, 16H42, 16H43); parent Y^{93} (16H43, 16H43a)
Sr^{94}	B chem, genet (16H43, 16H43a)		β^- (16H43, 16H43a)	~2 m (16H43, 16H43a)				fission U (16H43, 16H43a, 24D51); parent Y^{94} (16H43, 16H43a)
Sr^{95}	[A] genet (24D51a)		β^- (24D51a)	short (24D51a)				fission U, ancestor Zr^{95}, descendent Kr^{95} (24D51a)
Sr^{97}	[A] genet (24D51)		β^- (24D51)	short (24D51)				fission U, ancestor Zr^{97}, descendent Kr^{97} (24D51, 26A51)
$_{39}Y^{82}$	B chem, genet (78C52)			70 m (78C52)				spall Y, parent Sr^{82} (78C52)
Y^{83}	B chem, genet (78C52)			3.5 h (78C52)				spall Y, parent Sr^{83} (78C52)
Y^{84}	B chem, excit, sep isotopes (36R49)		β^+, EC (36R49)	3.7 h (36R49)	2.0 abs (36R49)	γ (36R49)		Sr^{84}-d-2n, Sr^{84}-p-n (36R49)
Y^{85}	B chem, genet (78C52)			5 h (78C52)				spall Y, parent Sr^{85} (78C52)

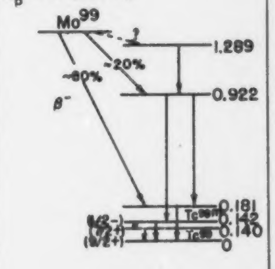
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{39}Y^{86}$	B chem, excit, sep isotopes (53C51)		β^+ (53C51)	14.6 h (53C51, 8H51b)	1.80 (~50%), 1.19 (~50%) spect (8H51b)	1.4 abs (8H51b); ~1.3 abs (53C51)		Sr-p-3n, Sr^{88}-p-3n (53C51); spall Nb, daughter Zr^{86} (8H51b)
Y^{87m}	A chem (71S39); chem, excit, cross bomb (2D40a)		IT (2D40a); no β^+ (8H51b)	14 h (2D40a, 8H51b, 58M51)		0.381 (K/L+M 5.41) spect conv (59G52); 0.384 (e/γ 0.28) spect conv, ion ch, conv-x coinc (58M51); 0.389 spect conv (8H51b); no γ >1 (58M51); conv >1 (8H51b)	see Rb^{87}  (9/2+) Y^{87m} 0.384 (1/2-) Y^{87} 0 EC β^+,EC (3/2-) 0.875 Sr^{87m} (1/2-) 0.390 (9/2+) 0	Sr-d-n (71S39, 2D40a, 58M50, 58M51); Sr-p-n (2D40a, 58M51); spall Nb, daughter Zr^{87} (8H51b); parent Y^{87} (58M50, 8H51b, 58M51)
Y^{87}	A chem (71S39); chem, excit, cross bomb (2D40a)		EC 99+%, β^+ ~0.3% (58M51); EC, β^+ (weak) (36R50)	80.0 h (58M51); 80 h (2D40a, 8H51b)	0.7 spect (58M51, 36R50)	0.485 (e/γ 0.0035) spect conv, scint spect, γ-x coinc (58M51); 0.390 (with Sr^{87m})	(58M51) Q_β^+ 2.1 (58M51)	Sr-p-n (2D40a, 58M51); Sr-d-n (71S39, 2D40a, 58M51) Sr^{84}-α-p (36R50); spall Nb (8H51b), Sb (37L50); daughter Y^{87m} (58M50, 8H51b, 58M51); parent Sr^{87m} (2D40a, 37L50, 58M50, 8H51b, 58M51)
Y^{88}	A chem (2D40a); chem, excit (2H42); mass spect (60H48)		EC (2D40a); EC 99+%, β^+ 0.19% (6P48)	104 d (10O46); 105 d (2D40a)	0.83 spect (6P48)	0.908 (e/γ 0.0003), 1.853 (e/γ 0.0001), 2.76 spect conv, spect (6P48); ~0.9 (e_K/γ 0.00034), ~1.85 (e_K/γ 0.00017) spect conv (44M52b); 0.908, 1.89 spect, γ-γ coinc (25D41); 1.87 Be-γ-n reaction (17S41); 2.8 (~1%) D-γ-n reaction (41G44)	see Rb^{88} Q_β^+ 3.70 (6P48)  (4-) Y^{88} EC β^+ 2.8 ~99% 1.85 ~1% ~99% (0+) 0 (6P48, NP5)	Sr-d-2n (29P40, 2H42, 41G44, 17B50); Sr-p-n (2D40a); Y-n-2n (2H42, 10O46); daughter Zr^{88} (8H51b)
Y^{88}	G not found: chem, cross bomb, sep isotopes (36R49)		β^+ (71S37)	2.0 h (71S39)				Sr-d (71S37, 71S39); Sr-p (2D40b, 2D40a); Y-n (71S37)
Y^{89m}	A chem, genet (18G51)		IT (18G51)	~14 s (18G51)		0.913 spect conv (73S51); 0.917 spect conv (8H51b); ~0.9 (K/L+M 7.0) spect conv (79B52); 0.92 (e/γ 0.01) spect conv, scint spect (74S51, 18G51)	 (18G52)	Y-n-n, daughter Zr^{89} (18G51)
Y^{89}		100 (1D39)					Y^{89}, I = 1/2 (87M50)	
Y^{90}	A chem, excit, cross bomb (71S37); chem, mass spect (60H48)		β^- (71S37)	61 h (37B46, 71S37); 62 h (11G49); 65 h (18N51)	2.18 spect (10L49); 2.24 spect (23L50); 2.25 spect (74B49); 2.27 spect (96M52); 2.2 spect, abs (33G51c); Ē (average) 0.90 ion ch (77C52)	no γ (33G51c, 74B49, 39G43); 1.4 (0.4%) abs (115S52); others (52M51)	Q_β^- 2.18 (10L49)  (74B49)	Y-d-p (71S37); Y-n-γ (71S37, 42S38, 2S47); Zr-n-p, Zr-d-α (42S40); Nb-n-α (42S38a, 42S40a); spall-fission Pt, Tl (2T47b), Bi (13P47, 11G49); fission Th (21T51); fission U, daughter Sr^{90} (16H42, 16H43, 38G46, 18N51)

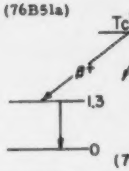
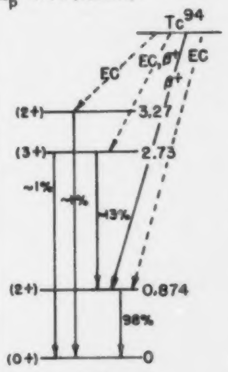
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{39}Y^{91m}$	A chem, genet (40G41)		IT (40G41)	51.0 m (28F51a); 50 m (40G41)		0.551 (K/L+M 6.00) scint spect (59G52); 0.61 (e/γ ~0.1) abs, abs conv (28F51a)	see Sr^{91}	Zr-n-p (66S43a); fission U, daughter Sr^{91} (40G41, 16H43, 28F51a)
Y^{91}	A chem, genet (16H40c, 16H43); chem, mass spect (72B51a, 60H48)		β^- (16H40c)	61 d (38G46, 10L49); 57 d (40G41, 16H40c, 19J44)	1.537 spect (10L49); 1.54 spect (15O49); 1.55 spect (16W49c, 24K49); 1.56 spect (16A50, 96M52)	1.2, 0.2 (both <0.1%) abs, coinc abs sec, γ-γ coinc (10L49)	 Y^{91m} (9/2+) 0.551 Y^{91} (1/2-) 0 ~0.1% 1.6 β^- ~100% Q_{β}^- 1.537 (10L49) (5/2+) 0 (10L49, 28F51a, 40A52)	Zr-n-p (66S43a); spall Sb (37L50); spall-fission Bi (11G49), U (11O51); fission Th (72B51), U^{233} (38G49), Pu (28F51, 13E51); fission U, daughter (~60%) Sr^{91} (40G41, 16H43, 28F51a)
Y^{92}	B chem (36L39); fission fragment range (32K48)		β^- (36L39)	3.60 h (40A52a); 3.5 h (28A43, 16H43a, 36L39)	3.60, 2.7, 1.3 spect (40A52a); 3.5 abs (58H51b); 3.4 abs (40G41); 3.6 abs (70B43a)	0.6 abs (40G41); 0.7 - 1.1 abs (58H51b)		Zr-n-p ([illegible], 66S43a, 28A43); fission Hg (p) ([illegible]); fission Th (72B51), Pu (32K48); fission U, daughter Sr^{92} ([illegible])
Y^{93}	B chem (16H43, 72B46, 72B51b, 70B51); fission fragment range (32K48)		β^- (72B51b)	10.0 h (72B51b); 11.5 h (16H43)	3.1 abs (72B51b)	0.7 abs (72B51b)		spall-fission U ([illegible]); fission Th (72B51), Pu (32K48); fission U, daughter Sr^{93} (16H43, 16H43a, 72B51b)
Y^{94}	B chem (16H43, 16H43a); fission fragment range (32K48)		β^- (16H43, 16H43a)	16.5 m (75B49); 20 m (24D51b, 16H43)	5.4 abs (75B49)	1.4 abs (75B49)		Zr-n-p (66S43a); fission U (16H43, 16H43a, 24D51b), Pu (32K48); daughter Sr^{94} (16H43, 16H43a)
Y^{95}	B chem, sep isotopes, excit (20K49)		β^- (20K49)	10.5 m (20K49); <1.5 h (70B51)				Zr^{96}-γ-p (20K49)
Y^{97}	[A] genet (24D51)		β^- (24D51)	short (24D51)				fission U, descendant Sr^{97}, parent Zr^{97} (24D51, 26A51)
$_{40}Zr^{86}$	[B] chem, genet (8H51b)		EC (8H51b)	~17 h genet (8H51b)				spall Nb, parent Y^{86} (8H51b)
Zr^{87}	A chem, excit, sep isotopes (36K49); chem, genet (8H51b)		β^+, EC (36K49)	94 m (8H51b); 120 m (36K49)	2.10 spect (8H51b); 2.0 abs (36K49)	0.65, 0.35 abs (36K49)		Sr-α-n, Sr^{86}-α-n (36K49); spall Nb, parent Y^{87m} (8H51b); Mo-γ-αn ([illegible])
Zr^{88}	B chem, genet (8H51b)		EC (8H51b)	85 d (8H52)		0.406 spect conv (8H51b)		spall Nb, parent Y^{88} (8H51b)

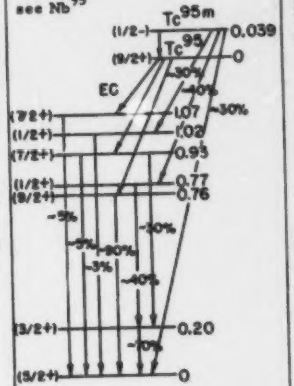
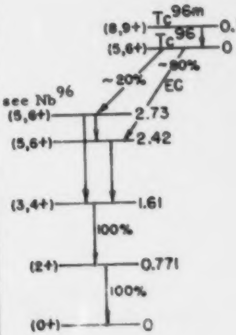
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{40}Zr^{89m}$	A chem, excit (2D40a)		IT, β^+ (weak) (73S51)	4.4 m (73S51); 4.5 m (2D40a)	2.5, -0.85 (both weak) (β^+/0.59 γ = 0.004) spect, scint spect, β-γ coinc abs (73S51, 73S52)	0.586 (e/γ 0.07, K/L+M 5.4) scint spect, spect conv (79B52, 73S51); 1.53 (-7%) scint spect (73S52)	Q_β^+ -3.4 see Sr^{89}	Y-p-n (2D40a); Zr-n-2n (?) (28A43); Zr-γ-n (73S51)
Zr^{89}	A chem, excit (42S38, 2D40a)		EC -75%, β^+ -25% (18G51)	79.3 h (74S51); 77 h (8H51b); 78 h (2D40a); 80 h (11O43)	0.910 spect (8H51b); 0.905 spect (74S51); 0.890 spect (73S51)	γ (with Y^{89m}): 0.92 (e/γ 0.01) spect conv, scint spect (74S51, 18G51); 0.913 spect conv (73S51); 0.917 spect conv (8H51b); -0.9 (K/L+M 7.0) spect conv (79B52)	Q_β^+ 2.84 (8H51b, 74S51)  Zr^{89m} (1/2-) 0.589 Zr⁸⁹ (9/2+) 0 β⁺ β⁺,EC(?) β⁺,EC 1.53 Y^{89m} (9/2+) 0.913 (1/2-) 0 (73S51, 73S52, HPS)	Y-d-2n (11O43, 18G51); Y-p-n (2D40a); Zr-n-2n (42S38, 42S40); Zr-γ-n (73S51); spall Nb (8H51b); Mo-n-α (42S40); parent Y^{89m} (18G51)
Zr^{90}		51.46 (24W48)						
Zr^{91}		11.23 (24W48)					Zr^{91}, I = 5/2 (87M50)	
Zr^{92}		17.11 (24W48)						
Zr^{93}	B chem (61S50)		β^- (61S50)	9.5 x 10^5 y sp act (33G53)	0.063 scint spect (33G53)	no γ (33G53)	Q_β^- 0.063 (33G53)  Zr⁹³ (5/2+) 79% β⁻ 21% Nb^{93m} (1/2-) 0.029 (9/2+) 0 (33G53)	fission U (61S50, 76B50); parent Nb^{93m} (33G53)
Zr^{94}		17.40 (24W48)						
Zr^{95}	A chem (2G40, 42S40); chem, genet (39G51)		β^- (42S40)	65 d (17B51a, 38G46); 66 d (2G48); 63 d (42S40)	0.371 (99%), 0.84 (1%) spect (5S52); 0.39 (98%), -1.0 (2%) spect (17N51); 0.365 (95%), -0.60 (weak), -1.1 (weak) spect (88S51b); -0.4 (98%), -1.0 (2%) abs (17B51a); 0.40 abs (26M48a); 0.40, 0.88 β-γ coinc abs, abs (14M51)	0.721 (e/γ 0.0024), no 0.92 γ spect, spect conv (5S52); 0.73, 0.92 (?) spect conv (17N51); 0.88 abs (17B51a); 0.91 coinc abs sec (26M48a); others (52M51)	Q_β^- 1.09 (5S52)  Zr⁹⁵ (5/2+) 1% β⁻ 99% (7/2+) 0.721 Nb^{95m} (1/2-) 0.231 Nb⁹⁵ (9/2+) 0 (5S52)	Zr-n-γ (42S40, 2S47); Zr-d-p (42S40, 20J51); Mo-n-α (42S40); spall-fission Bi (11G49, 66B51), Th (7N49a); fission U^{233} (38G48, 61S48), Pu (28F51); fission U, parent (-1%) Nb^{95m}, parent (-99%) Nb^{95} (621149, 17B51a, 20J51, 61S51b)
Zr^{96}		2.80 (24W48)						

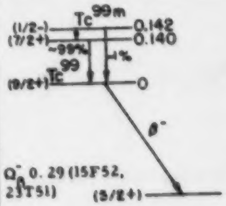
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{40}Zr^{97}$	A chem (2G40); chem, n-capt, sep isotopes (50B50a, 26M52)		β^- (2G40)	17.0 h (50B50a, 26M52, 32K51b, 2G40)	1.91 spect (50B50a); 1.9 abs (75S49); 2.2 abs (32K51b); 2.5 abs (26M52)	with Nb^{97m}: 0.747 (e/γ 0.015) spect, spect conv, β-γ coinc, γ-γ coinc, β-conv coinc (50B50a)	Q^-_β 2.66 (50B50a)  Zr^{97} β^- Nb^{97m} (1/2-) 0.75 Nb^{97} (9/2+) 0 (18G52)	Zr^{96}-n-γ (50B50a, 26M52); Zr-n-γ (42S40, 2S47); Mo-n-a (42S40); spall-fission Bi (66B51), Th (7N49a), U (6O47); fission Th (21T51), U (2G40, 16H41a), Pu (32K48) parent Nb^{97m} (50B50a); descendent Kr^{97} (24D51)
Zr^m	E (24C52)		IT (24C52)	0.83 s (24C52)		~0.50 scint spect (24C52)		Zr-n (24C52)
$_{41}Nb^{90}$	A chem, excit, cross bomb (20J51); chem, sep isotopes, cross bomb (76B49b, 29K49)		β^+ (20J51)	15.0 h (29K49); 15 h (76B49b); 18 h (20J51)	1.2 abs (29K49); ~1.7 abs (76B49b)	0.14, 1.14, 2.23 scint spect (76B51d); 2.0 abs (29K49)		Zr-d-2n (20J51); Zr^{90}-d-2n (29K49); Mo-d-a (20J51); Mo^{92}-d-a (29K49, 76B49b); Mo-γ-pn (22E52); daughter Mo^{90} (43D52)
Nb^{91m}	A chem, excit (20J51); chem, sep isotopes (16O51)		IT (76B49b)	64 d (76B49b); 60 d (20J51)		0.1045 (e/γ ~50, K/L 2.1) spect conv, scint spect (16O51); 0.105 (K/L+M 2.1) spect conv (4P51); Nb x (76B49b, 16O51)	 Nb^{91m} (9/2+) 0.105 Nb^{91} (1/2-) 0 EC (5/2+)	Zr^{90}-d-n (16O51); Zr-d-n (20J51); Mo^{94}-d-an (76B49b)
Nb^{91}	B genet (16O51)		[EC] (16O51)	long (16O51)		Zr x (16O51)	(18G52)	[Zr^{90}-d-n, daughter Nb^{91m}] (16O51)
Nb^{92}	B chem, excit (8J52a)		EC (8J52a)	~13 h (8J52a)		2.35 scint spect (8J52a)		Nb-p-pn (8J52a)
Nb^{92}	A chem, excit (42S38a)		EC, no β^- (lim 0.05%) (4P51); EC, no β^- (8J52a)	10.1 d (29K47); 9.8 d (60M48); 11 d (42S40a, 42S38a)	β^- (?): 1.3 cl ch (42S40a), abs (29K47); 0.6 abs (59M44)	0.930 (with EC) spect (4P51); 0.933, 1.84 (weak) scint spect (18T52); 1.0 abs (59M44, 29K47); 1.1 abs (1P45); Zr-x (1P45)		Y-a-n (1P45); Zr-p-n (59M44); Nb-γ-n (60M48, 22E52); Nb-n-2n (42S38a, 42S40a); Nb-d-t (37W46, 29K47); Mo-n-p (42S40); Mo^{94}-d-a (76B49b)
Nb^{92}	G not found: chem, excit (76B49b)		β^- (37W46)	21.6 h (37W46)				Nb-d (37W46)
Nb^{93m}	B genet (33G53)		IT (33G53)	3.65 y (33G53)		0.0292 (e/γ very large, K/L 0.14) spect conv (33G53)	 (33G53)	daughter Zr^{93} (33G53)
Nb^{93}		100 (37S36a)					Nb^{93}, I = 9/2 (87M50)	

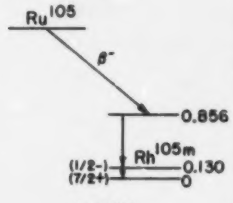
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{41}Nb^{94m}$	A n-capt, excit (1P37, 42S38a, 18G46b, 29K46)		IT 99+%, β^- ~0.1% (18G46b)	6.6 m (42S40a)	1.3 abs (18G46b)	0.0415 (e/γ large, K/L/M = 0.31/1.00/0.36) spect conv (42C50); 0.056 (e/γ large) abs conv (18G46b); 0.9 (weak) scint spect (38M51a); Nb K-x (18G46a, 18G46b)	 Nb94m (3,4-) 0.042 Nb94 (6,7+) 0 β- β- (2+) 0.9 (0+) 0 (18G52)	Nb-n-γ (1P37, 42S38a, 42S40a, 18G46a, 18G46b, 2S47); Nb-d-p (29K46, 37W46)
Nb^{94}	[A] n-capt (18G46b); chem, n-capt (63H52)		[β^-] (18G46b)	>5 x 10^4 y yield (63H52); >>100 y yield (18G46b, 18G48a)				Nb-n-γ (18G46b)
Nb^{95m}	A chem (13E46, 13E51a); chem, genet (61S51b)		IT (61S51b)	90 h (61S51b, 62H49); 84 h (5S52)		0.231 (e/γ very large) spect conv (5S52); 0.232 (K/L+M ~3.5) spect conv (4P51); 0.2 (e/γ very large) spect conv (62H49); Nb K-x (61S51b)	see Zr^{95}  Nb95m (1/2-) 0.231 Nb95 (9/2+) 0 β- (7/2,9/2+) 0.745 (5/2+) 0	Mo^{97}-d-α (76B49b); fission U, daughter (~1%) Zr^{95} (62H49, 17B51a, 20J51, 61S51b); spall-fission U (6F51); parent Nb^{95} (61S51b, 19L51)
Nb^{95}	A chem (39G46, 39G51); chem, excit, cross bomb (20J51)		β^- (39G51)	35 d (13E51b); 37 d (20J51)	0.160 spect (29F52); 0.159 spect (5S52); 0.148 spect (88S51b); 0.146 spect (62H49); 0.15 spect (17N51a); others (26M48b)	0.745 (e/γ 0.0024) spect, spect conv (5S52); 0.758 (e/γ 0.002) spect, spect conv (62H49); 0.77 (e/γ 0.0016, K/L = 4) spect conv (29F52); 0.77 spect, spect conv (17N51a); 0.75 spect conv (11R47)	Q_β^- 0.91 (5S52) (5S52)	Mo^{97}-d-α (76B49b); Mo-d-α (20J51); spall-fission Bi (66B51), U (6F51); fission U, daughter (~99%) Zr^{95} (62H49, 17B51a, 61S51b)
Nb^{96}	A chem, excit, sep isotopes (29K49a)		β^- (29K49a)	23.35 h (29K49a); 22.9 h (76B51)	0.750 (92%), 0.37 (8%) spect (4P51); 0.686 (92%), 0.37 (8%) spect (31J52); 0.75 spect (76B51)	0.216 (7%, e/γ <23 x 10^{-3}), 0.238 (10%, e/γ <16 x 10^{-3}), 0.45 (27%, e/γ 4 x 10^{-3}), 0.569 (61%, e/γ 1.7 x 10^{-3}), 0.770 (100%, e/γ 1.2 x 10^{-3}), 0.804 (6%, e/γ 1.3 x 10^{-3}), 0.840 (16%, e/γ 1.2 x 10^{-3}), 1.078 (52%, e/γ 0.5 x 10^{-3}), 1.187 (32%, e/γ 0.3 x 10^{-3}) spect conv, spect (4P51); 0.455, 0.545, 0.745, 0.9, 1.05, 1.1 spect, spect conv (31J52)	Q_β^- 3.16 (4P51, 74S51a) see Tc^{96}  Nb96 8% β- 92% 2.79 2.57 2.41 27% 61% 6% 1.98 1.85 10% 1.61 52% 32% 16% 0.770 100% 0 (4P51)	Zr^{96}-p-n (29K49a); Mo^{98}-d-α (76B51); spall-fission Bi (66B51); fission U (68C51a)
Nb^{97m}	A chem, excit, sep isotopes, genet (50B50a)		IT (50B50a)	60 s (50B50a)		0.747 (e/γ 0.015, K/L ≥4) spect, spect conv, β-γ coinc, γ-γ coinc, β-conv coinc (50B50a)	 Nb97m (1/2-) 0.75 Nb97 (9/2+) 0 β- (7/2+) 0.67 (5/2+) 0 (18G52)	Mo^{98}-γ-p (50B50a); daughter Zr^{97} (50B50a)
Nb^{97}	A chem, genet (2G40)		β^- (2G40)	72.1 m (26M52); 74 m (50B50a); 75 m (2G40)	1.267 spect (50B50a); 1.35 abs (75S49); 1.4 abs (32K51b, 26M52)	0.665 (e/γ ~0.0015) spect, spect conv (50B50a); 0.7 abs, β-γ coinc (26M52)		Mo-n-p (42S40); Mo-γ-p (42H47, 12P48, 22E52); fission U (2G40, 32K51b), Pu (32K51b); spall-fission U (6F51)
Nb^{98}	E chem, sep isotopes (76B49b)		β^- (76B49b)	30 m (76B49b)				Mo^{100}-d-α (76B49b)
Nb^{99}	B chem, excit, sep isotopes (23D50)		β^- (23D50)	2.5 m (23D50)	3.2 abs (23D50)			Mo^{100}-γ-p (23D50)

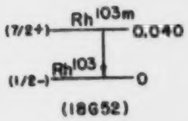
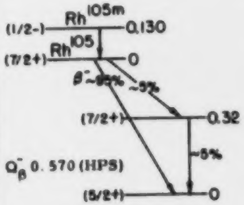
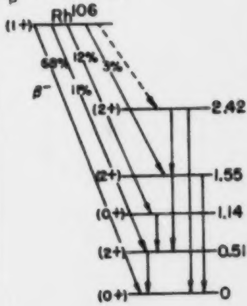
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{42}Mo^{90}$	B chem, genet (43D52)		β^+, EC (43D52)	5.7 h genet (43D52)		-0.1, other γ's abs (43D52)		spall Nb (43D52); parent Nb^{90} (43D52)
Mo^{91}	A excit (37B37a); chem, excit (42S38); chem, sep isotopes, excit (29K49, 23D49)		β^+ (42S38)	15.5 m (23D49, 25W48); 17 m (29K49, 37B39, 42S38)	3.7 abs (23D49); 2.7 cl ch (42S40)	no γ (23D49)		Mo-γ-n (37B39, 25W48, 22E52); Mo-n-2n (6H37, 42S38, 42S40, 30B52); Mo^{92}-n-2n (29K49); Mo^{92}-γ-n (23D49)
Mo^{91}	B chem, sep isotopes (23D49)		β^+ (23D49)	75 s (23D49); 73 s (25W48)	2.6 abs (23D49)	0.3 abs (23D49)		Mo^{92}-γ-n (23D49); Mo-γ-n (25W48)
Mo^{92}		15.86 (9W46)					Mo^{92}, I = 0 (87M50)	
Mo^{93m}	D chem, excit (29K46); chem, excit, cross bomb, sep isotopes (29K50a); chem, excit (76B52b); possibly Mo^{92m} or Mo^{94m} (HPS)		IT (29K50a)	6.95 h (76B52b); 6.75 h (29K50a)		0.262 (K/L 2.9), 0.69, 1.51 spect, spect conv (19R51); 0.256 (K/L 2.8), 0.7, 1.5 spect conv, scint spect (13A50b); 0.30 (e/γ 9), 0.70 (e/γ 0.005), 1.7 (e/γ -0) abs, abs conv, spect conv, conv-γ coinc (29K50a); γ_1 0.29, γ_2 0.69, γ_3 1.46 ($\gamma_1/\gamma_2/\gamma_3$ = 0.6/1/1) scint spect (76B52b) others (85S51)		Zr^{90}-α-n (29K50a); Zr-α-n (29K46); Nb-p-n (29K46, 19R51, 76B52b); Nb-d-2n (29K46, 37W46, 29K50a); Mo^{94}-n-2n (29K50a); not found by: Mo^{92}-n-γ (76B50a); Mo^{94}-γ-n (23D49); Mo^{92}-d-p (29K50a); not daughter Tc^{93} (76B50a)
Mo^{93}	B chem, n-capt (76B49)		EC (76B49)	>2 y (76B49)		Nb K-x (76B49)		Mo-n-γ (76B49)
Mo^{94}		9.12 (9W46)					Mo^{94}, I = 0 (87M50)	
Mo^{95}		15.70 (9W46)					Mo^{95}, I = 5/2 (87M50)	
Mo^{96}		16.50 (9W46)					Mo^{96}, I = 0 (87M50)	
Mo^{97}		9.45 (9W46)					Mo^{97}, I = 5/2 (87M50)	
Mo^{98}		23.75 (9W46)					Mo^{98}, I = 0 (87M50)	
Mo^{99}	A chem, n-capt, excit (42S38, 42S40)		β^- (42S38)	67 h (13S39); 68.3 h (10C49); 63.5 h (25W48); 64 h (42S40)	1.23 (-80%), 0.45 (-20%), -0.08 (weak) (?) spect (2B50a); 1.23 (87%), 0.54 (13%) spect (62M51); 1.25, others, spect (54M51); 1.2 abs (32K51c)	γ_1 0.040, γ_2 0.181 (K/L 5), γ_3 0.367, γ_4 0.741, γ_5 0.780 ($\gamma_3/\gamma_4/\gamma_5$ = 10/100/14) spect, spect conv (2B50a); 0.728, 0.360 (weak), 0.182 (weak) spect, β-γ, γ-γ coinc (62M51); 0.179, 0.168 spect conv (10C49); γ_4 0.745, γ_5 0.780, γ_6 0.850 ($\gamma_4/\gamma_5/\gamma_6$ = 100/50/30) spect (54M51); with Tc^{99m}: 0.0018, 0.140 (62M49, 62M51); 0.142 (63M51)	Q_β^- 1.37 (2B50a)  Mo99 ? 1.289 ~20% ~80% 0.922 β- 0.181 Tc99m 0.142 0.140 Tc99 0 (9/2+) (18G52)	Zr-α-n (14E46); Mo-d-p (13S39); Mo-n-γ (42S38, 13S39, 61M47, 2S47, 26M48c, 62M49); Mo^{98}-n-γ (61M47a); Mo-n-2n (42S40); Mo-γ-n (25W48, 22E52); spall Sb (37L50); spall-fission Pt, Tl (2T47b), Bi (13P47, 11G49, 66B51), Th (7N49a), fission Th (16H39d, 72B51, 21T51), U^{233} (61S48), U (16H39e, 24S40, 32K51c), Pu (32K48, 28F51); parent Tc^{99m} (13S39, 24S40, 62M49, 33G51e)

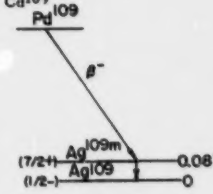
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{42}Mo^{100}$		9.62 (9W46)					Mo^{100}, I = 0 (87M50)	
Mo^{101}	A chem, n-capt (42S40); chem, n-capt, sep isotopes (61M47a)		β^- (42S40)	14.6 m (3M41); 14 m (16H41b)	1.2, 2.1 abs (31R52); ~1.0, 2.2 abs (3M41); 1.9 abs (42S40)	0.191 (K/L ~6), 0.960 (coinc with 1.2 β^-) spect conv, scint spect, β-γ, γ-γ coinc (31R52); 0.15 scint spect (38M51a)		Mo-n-γ (42S40b, 42S40, 24S40a, 3M41, 2S47, 50H51)· Mo^{100}-n-γ (61M47a); parent Tc^{101} (42S40b); fission U, parent Tc^{101} (24S40a, 37B41, 16H41, 16H41b, 3M41)
Mo^{102}	D chem (16H41)		β^- (16H41)	12 m (16H41); 11 m (76B49a)				fission U, parent Tc^{102} (16H41, 16H41b, 76B49a)
Mo^{105}	B chem, genet (70B43b)		β^- (70B43b)	~5 m (66S47)				fission U, ancestor Ru^{105} (70B43b)
$_{43}Tc^{92}$	D chem, sep isotopes (61M48)		β^+, EC (76B52c)	4.3 m (76B52c)	4.1 abs (76B52c)	1.3 abs (61M48)		Mo^{92}-d-2n (61M48)
Tc^{92}	D chem, excit, sep isotopes (29K48a)		EC (29K48a)	43.5 m (62M50); 47 m (29K48a)		0.389 spect, spect conv (62M50); 1.50 abs conv (29K48a)		Mo^{92}-d-2n, p-n (29K48a); Mo-p-n (62M50)
Tc^{93}	A chem (13S39); chem, excit, sep isotopes (29K48a)		EC 93%, β^+ 7% (29K48a 76B51d)	2.75 h (29K48a); 2.7 h (61M48, 5D39)	0.800 spect (76B51a); 0.83 abs (29K48a)	1.34 (coinc with β^+) scint spect, β-γ coinc abs (76B51d); 2.00 abs (29K48a); 2.4 abs (61M48)	Q_{β}^{+} 3.1 (76B51a)  (76B51a)	Mo^{92}-d-n (29K48a, 61M48); Mo-d-n (13S39); Mo-p-γ (5D39, 29K48a); not parent (7h) Mo^{93m} (76B50a)
Tc^{94}	B chem, excit (42G47); chem, excit, sep isotopes (61M48a)		β^+ ~75%, EC ~25% (62M50)	53 m (62M50); 50 m (61M48a)	2.41 (coinc with γ) spect, β-γ coinc (62M50); 2.5 abs (61M48a)	0.874 (e/γ ~10^{-3}), 1.85, 2.73, 3.27 spect, spect conv (62M50); 0.9 abs (61M48a)	Q_{β}^{+} 4.30 (62M50)  Tc^{94} EC EC, β^+ EC β^+ (2+) 3.27 (3+) 2.73 ~1% ~4% ~3% (2+) 0.874 98% (0+) 0 (62M50)	Mo-p-n (42G47, 34H48, 62M50); Mo^{94}-d-2n (61M48a); daughter Ru^{94} (12V52)

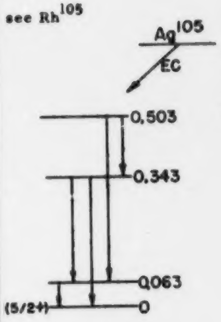
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{43}Tc^{95m}$	A chem (12C37, 12C39); chem, sep isotopes (61M48b)		EC 96+%, IT ~3%, β^+ 0. 2-0. 6% (62M50, 62M50a)	60 d (62M50); 52 d (14E47); 62 d (12C39)	0. 4 cl ch (62M50)	γ_1 0. 810 (e/γ 0. 001), γ_2 0. 201 (e/γ 0. 036), γ_3 0. 570 (e/γ 0. 002), γ_4 1. 02 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 0. 3/0. 7/0. 4/0. 03) spect, spect conv, γ-γ coinc (62M50); 0. 0390 spect conv (62M50a); 0. 80, 0. 20, 0. 58, 1. 03 scint spect (76B5la); 0. 8, 0. 2 abs (14E47, 61M48b)	see Nb^{95}  Tc95m Tc95 (1/2-) 0.039 (9/2+) 0 EC ~30% ~40% ~30% (7/2+) 1.07 (1/2+) 1.02 (7/2+) 0.93 (1/2+) 0.77 (9/2+) 0.76 ~5% ~5% ~90% ~3% ~30% ~40% (3/2+) 0.20 ~70% (5/2+) 0 (62M50, 62M50a, 18G52)	Mo-d-n (12C37, 12C39, 14E46); Mo-p-n (14E47); Mo^{95}-d-2n (61M48b)
Tc^{95}	A chem, sep isotopes (1E48, 61M48a)		EC (1E48); no β^+ (62M50)	20. 0 h (1E48); 20 h (61M48a)		0. 762 (~90%), 0. 932 (~5%), 1. 071 (~5%) spect conv, γ-γ coinc (62M50); 0. 76, 1. 07, no 0. 93 γ scint spect (76B5ld); 0. 78 abs (1E48)		Mo-a-p, Mo-p-n, Mo^{92}-a-p (1E48); Mo^{95}-d-2n (61M48a); Mo-p-n (62M50)
Tc^{96m}	B chem, excit (62M50); chem, excit, sep isotopes (62M52)		IT (62M50)	51. 5 m (62M50)		0. 0344 (K/L 1. 2) spect conv (62M50); Tc K-x (62M50)		Mo^{96}-p-n (62M52); Mo-p-n (62M50)
Tc^{96}	A chem (15E39); chem, excit, cross bomb (14E47); chem, excit, sep isotopes (61M48b)		EC (61M48b); no β^+ (62M50)	4. 20 d (31C50); 4. 35 d (62M50); 4. 2 d (61M48b); 4. 3 d (14E47)		γ_1 1. 119 (e/γ 3 x 10^{-4}), γ_2 0. 842 (e/γ 6 x 10^{-4}), γ_3 0. 806 (e/γ 6 x 10^{-4}), γ_4 0. 771 (e/γ 6 x 10^{-4}), γ_5 0. 312 (K/L 6. 4) ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 0. 17/1. 00/0. 82/1. 00/0. 0052) spect, spect conv, γ-γ coinc (62M50); 1. 65, 1. 89, 2. 39 (?) (all weak) scint spect (76B5la)	see Nb^{96}  Tc96m Tc96 (8,9+) 0.34 (5,6+) 0 ~20% ~80% EC (5,6+) 2.73 (5,6+) 2.42 (3,4+) 1.61 100% (2+) 0.771 100% (0+) 0 (62M50, 76B5la, 62M52, 18G52)	Nb-a-n (14E47); Mo-p-n (15E39, 14E47, 62M50); Mo-d-n (14E47, 13S39); Mo^{96}-d-2n (61M48b)
Tc^{97m}	A chem (22P37, 12C37); chem, genet (61M47b); excit, sep isotopes (61M48b)		IT (2H41, 14E47)	90 d (61M48b); 91 d (2H41); 95 d (14E47)		0. 0958 (K/L+M 1. 6) spect conv (62M50); 0. 097 (K/L ~2) spect conv(2H41); 0. 097 (e/γ very large) abs conv (61M48b); 0. 108 (e/γ large) abs conv (14E47)		Mo^{97}-d-2n (61M48b); Mo-d-n (12C37, 22P37, 12C39); Mo-p-n (14E47); daughter Ru^{97} (61M47b)
Tc^{97}	[A] genet (76B5lb)		[EC] (76B5lb)	>10^4 γ yield (76B5lb)				[daughter Tc^{97m}] (76B5lb)

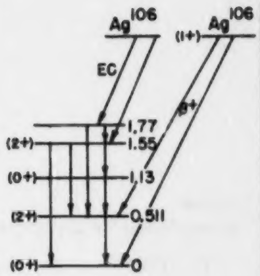
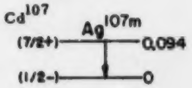
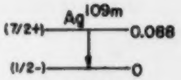
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{43}Tc^{99m}$	A chem, genet (13S39)		IT (13S39)	6.04 h (1B52); 5.9 h (33G51e); 6.6 h (13S39)		0.1403 (K/L 7.7), 0.1423 (~1%, K/L ~2.5) spect conv (63M51); 0.1412 (e/γ 0.11, K/L/M+N = 7.9/1/0.3), 0.0018 (e/γ very large) spect conv (62M49, 62M51); 0.140 (K/L ~9) spect, spect conv (2B50a); 0.139 (K/L ~10) spect conv (54M51)	 Tc99m (1/2-) (7/2+) 0.142 0.140 ~99% ~1% Tc99 (9/2+) 0 β⁻ (5/2+)	Ru-n-p (76B47); fission Th (72B51), U (24S40, 16H41, 33G51e); daughter Mo^{99} (13S39, 24S40, 62M49, 33G51e, 63M51); parent Tc^{99} (13S39, 16H41)
Tc^{99}	A chem (25L46, 53S46); chem, mass spect (3I47)		β^- (25L51, 53S51a)	2.12×10^5 y sp act (30F51); 2.2×10^5 y sp act (26P51)	0.290 spect (15F52); 0.292 spect (23T51); 0.296 spect (39W52); 0.30 spect (24K50a)	no γ (61M47, 53S51a, 30F51)	Q_n^- 0.29 (15F52, 23T51) (62M51, 63M51, 18G52) Tc^{99}, I = 9/2 (48K51)	fission U (3I47, 25L51, 53S51a); daughter Tc^{99m} (13S39, 16H41); descendent Mo^{99} (61M47)
Tc^{100}	A sep isotopes (64H52); sep isotopes, n-capt (76B52)		β^- (64H52)	15.8 s (76B52); 17.5 s (64H52)	2.8 abs (76B52); 2.4 abs (64H52)	0.55 scint spect (76B52c)		Mo^{100}-p-n (64H52); Mo-p-n (2D40); Tc^{99}-n-γ (76B52)
Tc^{101}	A chem, genet (42S40b)		β^- (42S40b)	14.0 m (3M41, 16H41b); 14.5 m (12P48); 16.5 m (60M48)	1.20 (>95%) abs; β-γ coinc (76B51a); 1.2 abs (42S40); 1.3 abs (3M41)	0.307 (coinc with β^-, K/L ~6) spect conv, β-γ coinc, scint spect (31R52); 0.30 (coinc with β^-), 0.56 (weak) scint spect, β-γ coinc (76B51a); 0.26 scint spect (38M51a); no 0.56 γ (31R52)		Mo^{100}-d-n (61M48); Ru-γ-p (12P48, 60M48); Rh-γ-2p (22E52); fission U, daughter Mo^{101} (24S40a, 37B41, 16H41, 16H41b, 3M41); daughter Mo^{101} (42S40b)
Tc^{102}	E genet (16H41)		β^- (16H41)	<25 s (76B49a); <1 m (16H41)				daughter Mo^{102} (16H41, 16H41b, 76B49a)
Tc^{105}	B chem, genet (70B43b)		β^- (70B43b)	short (70B43b)				fission U, daughter Mo^{105}, parent Ru^{105} (70B43b)
Tc^{107}	[E] genet (70B43b)		$[\beta^-]$ (70B43b)	<1.5 m (70B43b)				[fission U, parent Ru^{107}] (70B43b)
$_{44}Ru^{94}$	D chem, genet (12V52)		EC (12V52)	~57 m genet (12V52)				Mo-α-2n, parent Tc^{94} (12V52)
Ru^{95}	A chem, cross bomb, sep isotopes (1E48)		EC, β^+ (1E48)	1.65 h (1E48)	1.1 abs (1E48)	1.0, 0.5 abs (1E48)		Mo-α-n, Mo^{92}-α-n (1E48); Ru-n-2n (1E48); Ru-γ-n (60M48)
Ru^{96}		5.7 (16E43)						
Ru^{97}	A chem, excit (23S46); chem, cross bomb, sep isotopes (1E48)		EC (23S46)	2.8 d (23S46, 60M48)		0.217 spect (53M50a); 0.23 abs (23S46)		Mo^{94}-α-n (1E48); Ru-d-p (23S46); Ru-n-γ (23S46); Ru-n-2n (1E48); Ru-γ-n (60M48); spall Sb (37L50); parent Tc^{97m} (61M47b)
Ru^{98}		2.2 (16E43)						
Ru^{99}		12.8 (16E43)					Ru^{99}, I = 5/2 (19O52)	

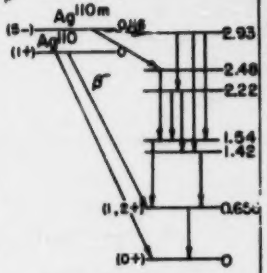
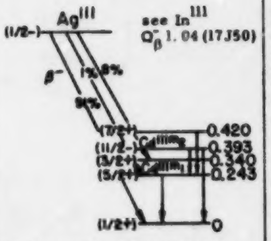
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{44}$Ru^{100}		12.7 (16E43)						
Ru^{101}		17.0 (16E43)					Ru^{101}, I = 5/2 (19O52)	
Ru^{102}		31.3 (16E43)						
Ru^{103}	A excit (12L36); chem (5N42, 39G46); chem, excit (23S51, 23S51b)		β^- (5N42)	39.8 d (38K50); 42 d (23S51); 41 d (77B45, 15H48); 45 d (5N42, 60M48)	0.217 (~99%), 0.698 (~1%) spect (38K50, 38K51c); 0.222 (94%), 0.684 (6%) spect (53M50a); 0.205 (strong), 0.670 (weak) spect (79S50); 0.350 (50%), 0.665 (50%) spect (15H48); 0.2 (92%), 0.7 (8%) abs, β-γ coinc (26M50)	0.498 (coinc with 0.22 β^-, e/γ ~0.01) spect, spect conv, β-γ coinc (38K50, 38K51c); 0.498 spect (46K52); 0.494 (e_K/γ 0.006, K/L 6.5) spect, spect conv (53M50a); 0.499 (K/L 8.5), 0.611 (K/L 4), 0.295 (?), 0.053 (K/L 1.0) spect conv (10C52); others (26M50, 23E52, 52M51); with Rh^{103m}: 0.040 (38K50, 53M50a, 79S50, 37W45, 10C52)	Q_β^- 0.75 (38K51c)	Ru-d-p (12L36, 23S51); Ru-n-γ (23S51, 7D38); Ru-γ-n (60M48); spall Sb (37L50); spall-fission Pb (13P47a), Bi (11G49); fission Th (72B51, 21T51), U^{233} (38G48, 61S48), U (5N41, 5N42, 39G51a, 23S51f), Pu (28F51); parent Rh^{103m} (23S51b)
Ru^{104}		18.3 (16E43)						
Ru^{105}	A chem (24S41); chem, excit (23S51c)		β^- (5N41)	4.5 h (76S51, 23S51d, 23S51a); 4.4 h (77B45)	1.150 spect (23D51); 1.15 spect (90S52); 1.3 abs (23S51d, 23S51a, 77B45)	0.726 (coinc with β^-) spect, β-γ coinc (23D51); 0.75 abs (23S51d); 0.7 abs (77B45); with Rh^{105m}: 0.130 (29A51, 23D51a, 90S52)	Q_β^- 2.01 (23D51)  Ru^{105} β^- 0.856 Rh^{105m} (1/2-) 0.130 (7/2+) 0 (18G52)	Ru-n-γ (7D38, 23S51c); Ru-d-p (12L36, 23S51c); spall Sb (37L50); spall-fission Pt (2T47b), Hg (v) (63S52), Tl (2T47b), Pb (13P47a), Bi (13P47, 11G49), U (6O48, 6F51); fission Th (24S41, 72B51), U (7D38, 5N41, 24S41, 70B43b, 77B45, 76S51, 23S51d); descendent Mo^{105} (70B43b), parent Rh^{105m} (23D51), ancestor Rh^{105} (5N41, 77B45, 76S51, 23S51c)
Ru^{106}	A chem (39G46, 33G46a); chem, mass spect (60H48)		β^- (39G51a, 33G51f)	1.0 y (33G51f, 66S46)	0.0392 spect (16A50); 0.038 spect (3F50b)	no γ (76S51a, 16A50)		spall Sb (37L50); spall-fission Bi (11G49), Th (7N49a), U (6F51); fission Th (72B51, 21T51), U^{233} (38G48, 61S48), U (33G51f), Pu (28F51); parent Rh^{106} (33G51f)
Ru^{107}	D chem (70B43b, 33G51g)		β^- (70B43b)	4 m (33G51g, 70B43b)	~4 abs (70B43b)			fission U, parent Rh^{107} (33G51g, 70B43b)
$_{45}$Rh^{99}	D chem (1E49)		β^+ (90S52)	4.5 h (90S52)	0.74 spect (90S52)			Ru-p-n (1E49, 90S52); Ru-d-n (1E49, 90S52)
Rh^{100}	B chem (23S51e); chem, genet (37L48)		EC ~95%, β^+ ~5% (37L48)	19.4 h (37L48); 21 h (23S51e)	3.0 spect (37L48)	1.2 abs (37L48); 1.8 abs (23S51e)		Ru-d-n (23S51e); daughter Pd^{100} (37L48)
Rh^{101}	B chem, excit (23S51g)		EC (23S51g)	4.3 d (37L48); 5.9 d (23S51g)		0.300, 0.148 spect conv (90S52); 0.35 spect conv, abs (37L48)		Ru-p-n (90S52); Ru-d-n (23S51g, 90S52); daughter Pd^{101} (37L48)

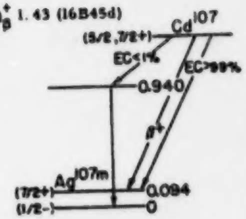
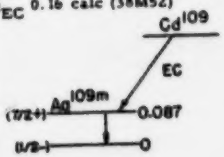
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{45}Rh^{102}$	A chem, excit (64M41)		β^-, β^+ (64M41); EC (?) (23S51h)	210 d (64M41); 215 d (15H47)	β^-: 1.0 cl ch (15H45); 1.1 abs (64M41) β^+: 1.1 cl ch (15H45)			Ru-d-n (23S51h); Rh-n-2n (64M41, 15H45); Rh-γ-n (60M48, 22E52)
Rh^{103m}	A chem, excit (9F44); chem (33G46a, 33G51f); chem, genet (23S51b)		IT (9F44, 37W45)	57 m (33G51f); 56 m (53M50a); 52 m (9F47); 45 m (37W45)		0.0400 (K/L+M 0.2) spect conv, β-γ coinc (38K50, 38K51c); 0.0404 (e/γ very large) spect conv (53M50a); 0.0396 (K/L 0.1) spect conv (10C52); 0.040 spect conv (79S50); abs conv (37W45); 0.042 abs conv (9F47)	 (18G52)	Rh-d-pn, Rh-p-p (15H48); Rh-n-n (9F44); Rh-e⁻-e⁻, Rh-x rays (37W45); fission U, daughter Ru^{103} (23S51b); daughter Pd^{103} (48B46, 53M50a)
Rh^{103}		100 (57C43)					Rh^{103}, I = 1/2 (49K50)	
Rh^{104m}	A n-capt (12A35)		IT (17P38, 28A43a)	4.4 m (32C39); 4.7 m (38M51, 58C47); 4.3 m (9F47)		0.052 scint spect (38M51); scint spect, ion ch (31K51); others (28A43a, 14O40, 15H47)		Ru-p-n (2D40); Rh-n-γ (12A35, 1P37, 17P38, 34G46, 2S47, 50H51); Pd-γ-p (42H47); parent Rh^{104} (17P38, 9F47)
Rh^{104}	A n-capt (12A35); genet (17P38)		β^- (17P38)	44 s (12A35, 17P38)	2.6 spect (15H47); 2.3 abs (18S43); cl ch (32C39); 2.5 abs (28M40)	0.04, 0.18, 0.95 abs, abs conv (58C47)		Rh-n-γ (12A35, 17P38, 34G46); daughter Rh^{104m} (17P38, 9F47)
Rh^{105m}	A chem, genet (23D51)		IT (23D51)	45 s (23D51)		0.130 (e/γ ~3, K/L 1.5) scint spect, spect conv (29A52); 0.127 spect conv (90S52)	 (1/2-) Rh^{105m} 0.130 (7/2+) Rh^{105} 0 β^- ~3% (7/2+) 0.32 ~5% Q_{β}^{-} 0.570 (HPS) (5/2+) 0 (18G52)	daughter Ru^{105}, parent Rh^{105} (23D51)
Rh^{105}	A chem, genet (5N41); chem, genet (23S51c)		β^- (5N41)	36.5 h (23S51c); 37 h (77B45); 34 h (5N41)	0.570 (~96%), 0.25 (~4%) spect (23D51, 23D51a); 0.57 spect (90S52); 0.26 (~10%) β-γ coinc abs (76B52a)	0.322 (~10%, coinc with 0.26 β^-), 0.157 (very weak), 0.080 (?) scint spect, β-γ coinc abs (76B52a); 0.320 (~3%) scint spect (23D51a); ~0.3 (~8%, not coinc with 0.6 β^-) abs, β-γ coinc (26M51); 0.33 (weak) abs (23S51i)		Ru-d-n (23S51i, 90S52); Rh-t-p (29K48); Pd-γ-p (12P48); spall-fission U (6F51); fission Th (72B51, 21T51), U (5N41, 76S51), Pu (32K48); descendent Ru^{105} (5N41, 77B45, 76S51, 23S51c), daughter Rh^{105m} (23D51)
Rh^{106}	A chem, genet (33G46a, 33G51f)		β^- (33G51f)	30 s (33G51f); 40 s (66S46)	3.53 (68%), 3.1 (11%), 2.44 (12%), 2.0 (3%), others (6%) spect (13A52); 3.55 (82%), 2.30 (18%) spect (6P47a); 3.5, ~2.3 abs, β-γ coinc (15J49)	γ_1 0.513 (e_K/γ 0.004, K/L 8), γ_2 0.624 (e_K/γ 0.002), γ_3 0.87, γ_4 1.045, γ_5 1.55, γ_6 2.41 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 100/53/3/8/2.5/1) spect, scint spect, spect conv (13A52); 0.510, 0.622 spect conv (10C52); 0.51 (17%), 0.73 (17%), 1.25 (~1%) spect, β-γ, γ-γ coinc (6P47a); ~0.5 (e_K/γ 0.005), ~0.7 (e_K/γ <0.003) spect conv (44M50); others (39A52)	Q_{β}^{-} 3.53 (13A52)  (1+) Rh^{106} 68% 12% 3% 11% β^- (2+) 2.42 (2+) 1.55 (0+) 1.14 (2+) 0.513 (0+) 0 (13A52)	fission U, daughter Ru^{106} (38G46, 33G51f); fission Pu (28F51)

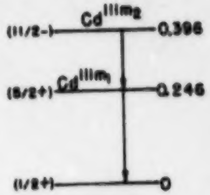
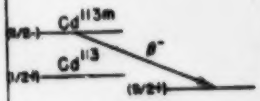
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{45}Rh^{107}$	D chem, genet (70B43b)		β^- (70B43b)	26 m (33G51g); 24 m (70B43b)	1.2 abs (70B43b)			Pd-γ-p (22E52); fission U, daughter Ru^{107} (70B43b, 33G51g)
Rh^{109}	[A] genet (77S51)		[β^-] (77S51)	<1 h (77S51)				[fission U, parent Pd^{109}] (77S51)
$_{46}Pd^{100}$	B chem, excit (37L48)		EC (37L48)	4.0 d (37L48)		0.09, 1.8 abs (37L48)		Rh-d-5n (37L48); spall Sb (37L48, 37L50); parent Rh^{100} (37L48)
Pd^{101}	B chem, genet (37L48)		EC 90%, β^+ 10% (37L48, 1E49)	8 h (37L50); 9 h (1E49)	2.3 spect (37L48); 0.5 abs (1E49)	no γ (37L48)		Ru-α-n (1E49); Rh-d-4n (37L48); spall Sb (37L48, 37L50); parent Rh^{101} (37L48)
Pd^{102}		0.8 (37S36a)						
Pd^{103}	A chem, genet (48B46a); chem, excit (36M47)		EC (48B46a)	17.0 d (36M47, 48B46a)		Rh K-x (36M47, 53M50a); no γ (36M47, 53M50a); with Rh^{103m}: 0.040 (38K50, 53M50a, 79S50, 10C52)		Rh-α-p3n (53M50a); Rh-d-2n (36M47, 37L48); Rh-p-n (36M47); Pd-n-γ (48B46a, 78S50); spall Sb (37L50); parent Rh^{103m} (48B46a, 53M50a)
Pd^{104}		9.3 (37S36a)						
Pd^{105m}	E excit (9F52a)		IT (9F52a)	~23 s (9F52a)		0.20 (e/γ ~0.4) (9F52a)		Pd-n-2n, Pd-n-n (9F52a)
Pd^{105}		22.6 (37S36a)					Pd^{105}, I = 5/2 (99B51)	
Pd^{106}		27.2 (37S36a)						
Pd^{107}	B chem (26P49a)		β^- (26P49a)	~7 x 10^6 y sp act (26P49a)	~0.04 abs (26P49a)			fission U (26P49a)
Pd^{108}		26.8 (37S36a)						
Pd^{109m}	D n-capt (31K51); excit, cross bomb, n-capt (9F52a)		IT (31K51, 9F52a)	4.8 m (9F52a)		0.173 scint spec (31K51); 0.160 (e/γ ~0.6) (9F52a)		Pd-n-2n, Pd-n-γ (9F52a); Ag-n-p (9F52a)
Pd^{109}	A n-capt (12A35); chem, excit (39K37); chem, mass spect (37R46, 67B49a)		β^- (39K37)	13.6 h (11M53); 13.1 h (25W48); 13 h (39K37, 77S51); 14.1 h (60M48)	0.961 spect (20K52); 0.95 spect (7S49b, 38K51c); others (2H46, 39K37, 77S51)	with Ag^{109m}: 0.087 (e/γ >11, K/L+M 1.3) spect conv (7S49b); no γ (77S51); others (52M51)	Q_β^- 1.05 (HPS) see Cd^{109}  Pd^{109} β^- (7/2+) Ag^{109m} 0.087 (1/2-) Ag^{109} 0 (18G52)	Pd-γ-n (12P48, 60M48, 25W48, 22E52); Pd-d-p (39K37); Pd-n-γ (12A35, 39K37, 2S47, 9O49, 50H51); Ag-d-2p (2H46, 112S51); Ag-n-p (4F38b); Ag-t-He^3 (29K47a); spall Sb (37L50), Ta (22N52); spall-fission Bi (11G49, 66B51), U (6F51); fission Th (21T51), U (77S51), U^{233} (61S48), Pu (32K48); parent Ag^{109m} (24S41, 7S49b, 77S51)
Pd^{110}		13.5 (37S36a)						

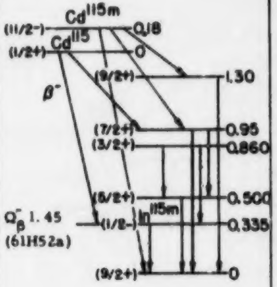
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{46}$Pd^{111m}	B chem, genet (66M52)		IT 75%, β^- 25% (66M52)	5.5 h (66M52)		0.16, 1.77 scint spect (66M52)		Pd-d-p, parent Ag^{111} (66M52)
Pd^{111}	A n-capt (12A35); chem, genet (24S41)		β^- (39K37)	22 m (66M52); 26 m (24S41)	2.13 spect (20K52); 2.15 spect (66M52); 3.5 abs (70B43b)	0.38, 0.56, 0.65, 0.73 scint spect (66M52)		Pd-d-p (12A35, 39K37); Pd-n-γ (12A35, 39K37, 2S47); spall Sb (37L50); spall-fission Bi (66B51); fission Th (24S41), U (24S41, 5N40a); parent Ag^{111} (39K37, 24S41)
Pd^{112}	A chem, genet (5N40a, 24S41)		β^- (5N40a)	21 h (77S51)	0.2 abs (77S51)	no γ (77S51)		In-p-4p, Pd-α-2p (112S51); spall Sb (37L50); spall-fission Bi (11G49, 66B51), Th (7N49a), U (6F51); fission Th (24S41, 21T51), U^{233} (61S48), Pu (32K48); fission U, parent Ag^{112} (5N40a, 5N40b, 24S41, 77S51)
$_{47}$Ag^{102}	E excit (17E39)			16 m (17E39)				Pd-p-n (17E39)
Ag^{104}	B excit (17E39); chem, excit, sep isotopes (11M52a)		β^+, EC (37L50)	1.2 h (17E39, 11M52a)				Pd-p-n (17E39); Cd^{106}-d-α (11M52a); spall Sb (37L50)
Ag^{104}	B chem, genet (32J52), chem, excit, sep isotopes (11M52a)		β^+ (32J52)	27 m (32J52)	2.70 spect (32J52)	0.118, 0.556, 0.148 (?), 0.179 (?) spect conv (32J52)		Cd^{106}-d-α (11M52a); daughter Cd^{104} (32J52)
Ag^{105}	A excit (17E39); chem, excit (16B47a)		EC (44G50)	40 d (44G50); 45 d (17E39)		0.0625 (e/γ very large, K/L >5), 0.280 (coinc with 0.063 γ, K/L 8), 0.343 (K/L 5.8), 0.440 (K/L 7), weak γ's: 0.154, 0.181, 0.391 spect conv, spect, γ-γ coinc (61H52); 0.064, 0.220 (weak), 0.278, 0.340, 0.437 (weak) spect (53M50b); 0.281, 0.319, 0.331, 0.345, 0.393, 0.443 spect conv (32J52); others (17E39, 20D42c)	see Rh^{105}  (61H52)	Rh-α-2n (16B47a, 44G50, 53M50b, 61H52); Pd-p-n (17E39, 44G50); Pd-d-2n (44G50, 53M50b, 61H52); Pd-α-p (44G50); spall Sb (37L50)

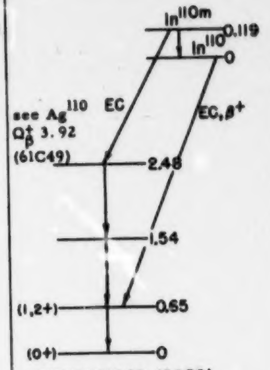
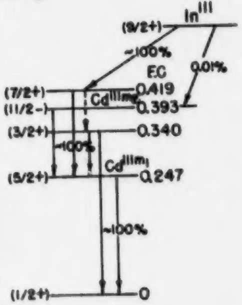
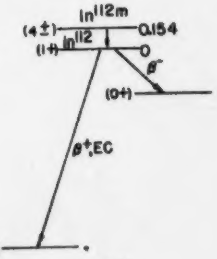
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{47}$Ag^{106}	A excit (37B37a, 6H37); chem, excit, cross bomb (39K37, 1P38)		β^+ (39K37); β^- (?) ~2% (79B51)	24.0 m (79B51); 24.5 m (1P38); 24.4 m (2D38); 24.3 m (60M48)	β^+: 1.95, 1.5 spect (79B51); 2.0 abs (4F38b); 1.9 cl ch (1P38) β^- (?): 0.45 spect (79B51); conv: ~0.5 (weak) spect conv (79B51)	~0.5, >0.6 (weak) spect conv, scint spect, abs (79B51) no γ (4F38b, 1P38)	 Ag^{106} EC (1+) Ag^{106} β^+ 1.77 (2+) 1.55 (0+) 1.13 (2+) 0.511 (0+) 0	Rh-a-n (1P38, 19K39, 16B47a); Pd-d-n (39K37, 1P38); Pd-p-γ (2D38); Pd-p-n (2D38, 17E39); Ag-n-2n (6H37, 1P38); Ag-d-t (29K47); Ag-γ-n (37B37a, 37B39, 60M48, 55S51, 22E52, 79B51); Ag-e$^-$-e$^-$n (59S48); Ag-d-p2n (9K40b); Cd-n-p (1P38)
Ag^{106}	A chem, excit, cross bomb (39K37 1P38)		EC (65H44)	8 2 d (1P38); 8.3 d (44G49); 7 5 d (39K37)		0.220, 0.409, 0.511 (K/L 8), 0.620, 0.717, 0.815, 1.04, 1.24, 1.55 spect conv (61H52); 0.515, 0 722, 1.04, 1.54 spect (53M50b); 0.72, 1.06, 1.63 spect (20D42c)	see Rh^{106} (18G52)	Rh-a-n (1P38, 16B47a, 53M50b, 61H52); Pd-d-n (39K37, 1P38, 61H52); Pd-p-n (2D38, 17E39); Ag-n-2n (1P38, 39K37, 36S51); Cd-n-p (1P38); spall Sb (37L50)
Ag^{107m}	A chem, genet (6A40, 2H41b)		IT (6A40)	44 3 s (16B45d, 16B47); 44 s (40W51)		0.094 (e/γ ~16, K/L 0.92) spect conv (16B47); 0.093 spect conv (6V39, 2H41)	see Cd^{107}  (18G52)	Ag-e$^-$-e$^-$ (37W45b); Ag-n-n (9F44); Ag-γ-γ (31F41, 37W45b, 24T45); Ag^{107}-γ-γ (40W51); daughter Cd^{107} (6A40, 2H41b, 16B45c, 2H46, 16B47)
Ag^{107}		51.35 (24W48)					Ag^{107}, I = 1/2 (87M50)	
Ag^{108}	A chem, n-capt (12A35); excit, cross bomb (1P38)		β^- 98.5%, EC 1 5% (12P52)	2.3 m (12A35, 12P48, 60M48, 37B39); 2.4 m (9F44)	1.5 scint spect (45G52)	0.45, 0.66 scint spect (12P52); 0.43, 0.60 scint spect (45G52)		Pd-p-n (2D38, 17E39), Ag-n-γ (12A35, 9F44, 2S47, 9O49, 50H51, 36S51); Ag-e$^-$-e$^-$n (59S48); Ag^{107}-n-γ (9F44a); Ag-γ-n (37B39, 12P48, 60M48, 22E52); Ag-d-p (9K39, 9K40b); Cd-n-p (1P38)
Ag^{109m}	A chem, genet (2H41b)		[illegible] (2H41b)	39.2 s (16B46c, 16B47); 40 s (40W51, 2H41b, 37W45b)		0.0875 spect conv (10C50b); 0.087 (e$_K$/γ ~6, K/L+M 0.75) spect conv (34H52); 0.087 (e/γ ≥11, K/L+M 1.3) spect conv (7S49b); 0.087 spect conv (2H46, 16B47)	 (18G52)	daughter Pd^{109} (24S41, 7S49b); Ag-n-n (9F44); Ag-γ-γ (31F41, 37W45b, 24T45); Ag^{109}-γ-γ (40W51); Ag-e$^-$-e$^-$ (37W45b); daughter Cd^{109} (2H41b, 16B45c, 2H46)
Ag^{109}		48.65 (24W48)					Ag^{109}, I = 1/2 (87M50)	

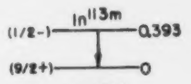
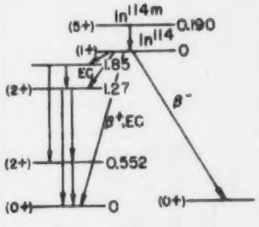
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{47}Ag^{110m}$	A chem, n-capt (35R38); resonance neutron activation (18G46c); chem, sep isotopes, n-capt (18G46d); chem, mass spect (67B49a)		β^-, IT (7S49c, 56M50, 10C50a); IT ⩾3% (7S49c); no EC (lim 3%) (20D47a); no β^+: lim β^+/β^- 0.002% (2E49); lim β^+/β^- 0.05% (41M51)	270 d (44G50, 10C50a); 225 d (12L38d)	with Ag^{110m} and Ag^{110}: 0.087 (-58%), 0.530 (-35%), 2.12 (-3%), 2.86 (-3%), others (?) spect (7S49c); 0.088 (65%), 0.520 (33%), 2.89 (-2%) spect (31A51); 0.590, 2.24, 2.91 spect (88S51a); 0.09 (coinc with γ), 0.57 (coinc with γ), 0.19 (?) abs, β-γ coinc (46M49); 0.09, 0.59 cl ch (2E49); 0.59 spect (11R47)	0.116 (e/γ very large, K/L 1.3), 0.656 (e/γ 0.0025), 0.676, 0.706, 0.759, 0.814, 0.885, 0.935, 1.389, 1.516 spect conv, spect, β-γ coinc, γ-γ coinc (7S49c); 0.116 (conv in Ag), 0.438, 0.446, 0.471, 0.499, 0.542, 0.575, 0.619, 0.657, 0.677, 0.705, 0.723, 0.764, 0.817, 0.884, 0.937, 1.384, 1.504 spect, spect conv (10C50a); 0.116 (K/L+M 1.8), 0.447, 0.618, 0.655 (K/L+M 4.3), 0.687, 0.706 (K/L+M 6.6), 0.740, 0.759 (K/L+M 6.5), 0.815 (K/L+M 4.1), 0.883 (K/L+M 4.2), 0.932 (K/L+M 6.5), 1.386 (K/L+M 6.5), 1.480, 1.506 (K/L+M 4.5) spect conv (31A51); 0.656 (K/L+M 14) spect conv (40K52); 0.66, 0.90, 1.40 spect conv, spect (11R47); -0.7, -0.9 (coinc with 0.7 γ) γ-γ coinc abs (5Y49); 1.7 < γ < 2.2 Be-γ-n reaction (38M50a); others (52M51)	see In^{110} Q_β^- 3.02 (7S49c)  Ag110m Ag110 (5-) (1+) 0.116 β⁻ 2.93 2.48 2.22 1.54 1.42 (1,2+) 0.656 (0+) 0 (7S49c, 18G52)	Pd-d-2n (44G50); Ag-n-γ (35R38, 12L38d, 30A38, 14M38, 2S47); Ag^{109}-n-γ (18G46d); Ag^{109}-d-p (44G50); Ag-d-p (9K39, 9K40b, 65H44a); spall Sb (37L50); parent Ag^{110} (56M50)
Ag^{110}	A n-capt (12A35); sep isotopes, n-capt (9F44a); chem, genet (56M50)		β^- (1P38)	24.2 s (42H46a); 22 s (12A35, 1P38)	2.24 (-60%), 2.82 (-40%) scint spect (45G51a)	0.66, -0.9 (weak) scint spect (45G51a)	Q_β^- 2.90 (HPS)	Ag-n-γ (12A35, 46G36, 9F44, 2S47); Ag^{109}-n-γ (9F44a); Cd-n-p (1P38); Cd-γ-p (42H46a, 42H47); daughter Ag^{110m} (56M50)
Ag^{111m}	F genet (80S52)			[<5 m] (80S52)				Pd-d-n, parent Cd^{111m_2} (80S52)
Ag^{111}	A chem, excit (39K37); chem, excit, cross bomb (1P38)		β^- (39K37)	7.6 d (61S51c); 7.5 d (17J50, 39K37, 1P38)	1.04 (91%), 0.80 (1%), 0.70 (8%) spect (17J50); 1.06 spect (66M51, 53M50b); 1.1 (93.5%), 0.7 (6.5%) abs (78S50)	γ_1 0.243 (e/γ <0.08), γ_2 0.340 (e/γ -0.015) (γ_2/γ_1 - 8) spect, spect conv, β-γ coinc, γ-γ coinc (17J50); 0.33 (-6.5%) abs (78S50)	see In^{111} Q_β^- 1.04 (17J50)  Ag111 (1/2-) β⁻ 1% 8% 91% (7/2+) (11/2-) (3/2+) (5/2+) Cd111m2 Cd111m1 0.420 0.393 0.340 0.243 (1/2+) 0 (17J50, 13E51c, 66M51, 66M51e, 18G52)	Pd-d-n (39K37, 1P38, 9Z49); Pd-a-p (1P38); Ag-a-2p (66M51); Ag-t-p (29K47a); Cd-n-p (1P38); Cd-γ-p (42H47, 23D49a); spall Sb (37L50), Ta (22N52); spall-fission Bi (11G49, 66B51), Th (7N49a), U (6O48, 6F51), U (C) (13H51); fission Th (21T51), U (5N40a, 24S41, 61S51c), Pu (28F51); parent Cd^{111m_1} (13E51c), daughter Pd^{111} (39K37, 24S41, 17J50), daughter Pd^{111m} (66M52)
Ag^{112}	A chem excit, cross bomb (1P38)		β^- (1P38)	3.20 h (74S51a); 3.2 h (1P38)	4.2 scint spect (27P51a); 3.6 abs (77S51); 3.5 abs (74S51a)	0.625, 1.40 (40A52b); 0.86 abs (77S51); no γ coinc with 3.5 β^- (74S51a)		Cd-n-p (1P38); Cd-γ-p (42H47); In-n-a (1P38); spall Sb (37L50); spall-fission Bi (66B51), U (6O47, 6F51); fission Th (21T51), U^{233} (61S48); fission U, daughter Pd^{112} (5N40a, 5N40b, 24S41, 77S51)

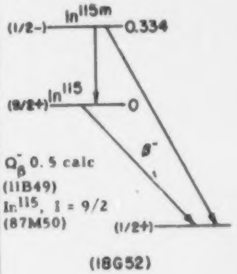
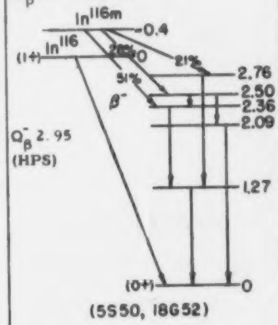
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{47}\text{Ag}^{113}$	A chem (21T47); chem, sep isotopes, excit (23D49a)		β^- (21T47)	5.3 h (21T47, 23D49a)	2.0 scint spect (27P51a); 2.1 abs (23D49a); 2.2 abs (21T47)	no γ (21T47, 23D49a;	Q_β^- 2.0 (HPS)	Cd^{114}-γ-p (23D49a); Cd-γ-p (23D49a); spall-fission Bi (66B51), U (6F51); fission U (21T47)
Ag^{114}	B chem (21T47, 66S47); chem, excit, sep isotopes (23D49a)		β^- (23D49a)	2 m (23D49a); 3 m (66S47)	hard β^- (23D49a)			Cd^{114}-n-p (23D49a); fission U (21T47, 66S47)
Ag^{115}	A chem (21T47, 66S47); chem, excit, sep isotopes (23D49a)		β^- (21T47)	20 m (23D49a, 66S47); 21 m genet (1W52); 22 m (21T47)	~3 abs (21T47, 23D49a)	no γ (23D49a)		Cd-γ-p (23D49a); Cd^{116}-γ-p (23D49a); fission U (21T47, 66S47); parent (91%) Cd^{115}, parent (9%) Cd^{115m} (1W52)
$_{48}\text{Cd}^{104}$	B chem, excit (32J52)		β^+ (32J52)	59 m (32J52)	0.93 spect (32J52)	0.0666 (K/L+M ~10), 0.0835 (K/L+M ~15), 0.124, 0.134, other γ's spect conv (32J52)		Ag-p-4n (32J52); parent (24 m) Ag^{104} (32J52)
Cd^{105}	B cross bomb (44G50); chem, excit (32J52)		EC, β^+ (44G50)	57 m (44G50); 55 m (32J52); 65 m (54K52)	1.68 spect (32J52); 1.5 abs (44G50)	0.0255, 0.0494, 0.0525, 0.262, 0.293, 0.308, 0.312, 0.317, 0.321, 0.341, 0.347, 0.433, 2.1 spect conv, scint spect (32J52)		Pd-α-n (44G50); Ag-p-3n (32J52, 54K52); Cd-n-2n (44G50)
Cd^{106}		1.215 (28L48)						
Cd^{107}	A chem (5D39); chem, n-capt, sep isotopes (2H46)		EC 99+%, β^+ 0.31% (16B45d, 55B50)	6.7 h (5D39)	0.32 spect (16B45d, 16B45e)	0.846 (0.4%, e/γ ~10^{-3}) spect, spect conv (16B45d, 16B45e); 0.7 abs (2H41); with Ag^{107m}: 0.094 (16B45c, 16B47, 6V39, 2H41)	Q_β^+ 1.43 (16B45d)  Cd107 (5/2,7/2+) EC<1% EC>99% 0.940 β+ Ag107m (7/2+) 0.094 (1/2-) 0 (18G52)	Ag-p-n (5D39, 6V39); Ag-d-2n (9K39, 6A40, 9K40b, 2H41b); Ag-α-p3n (2H46); Cd^{106}-n-γ (2H46, 18G46d); spall Sb (37L50); spall-fission U (6F51); parent Ag^{107m} (6A40, 2H41b, 16B45c, 2H46, 16B47)
Cd^{108}		0.875 (28L48)						
Cd^{109}	A chem (9K40b); chem, n-capt, sep isotopes (2H46)		EC (L/K 0.28) (38M52); EC (16B46c); no β^+ (26D51)	470 d (44G50); 330 d (16B46c)		with Ag^{109m}: 0.0875 spect conv (10C50b); 0.087 (e_K/γ ~6, K/L+M 0.75) spect conv (34H52); 0.087 (e/γ ≥11, K/L+M 1.3) spect conv (75491b)	see Pd^{109} Q_{EC} 0.16 calc (38M52)  (18G52)	Pd-α-n (44G50); Ag-d-2n (9K40b, 2H41b, 44G50); Ag-α-pn (2H46); Cd^{108}-n-γ (2H46, 10C50b, 59C51); spall Sb (37L50); parent Ag^{109m} (2H41b, 16B45c, 2H46, 16B46c)

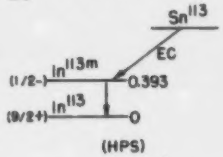
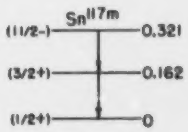
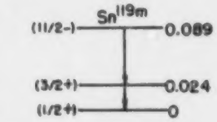
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{48}Cd^{110}$		12.39 (28L48)					Cd^{110}, I = 0 (87M50)	
Cd^{111m_2}	A chem (27D38); chem, sep isotopes, n-capt (18G48a)		IT (31F41, 37W45b)	48.6 m (66M51); 48.7 m (37W45b)		γ_1 0.150 (e/γ -3, K/L 2.0), γ_2 0.246 (e/γ 0.064, K/L 5.1) spect conv (66M51, 66M51a); γ_1 (e/γ 2.3) (calc from 14S51, 66M51); γ_1 0.149, γ_2 0.247 scint spect (14S51); γ_1 0.146, γ_2 0.238 spect conv (15H48a)	see Ag^{111} and In^{111}  Cd111m2 (11/2-) 0.396 Cd111m1 (5/2+) 0.246 (1/2+) 0 (17J50, 13E51c, 66M51, 18G52)	Pd^{108}-a-n (2H48); Pd-a-n (66M51); Ag-a-pn (2H48, 66M51); Cd-n-n or Cd-n-γ (27D38, 15H48a); Cd-γ-γ (31F41, 37W45b, 24T45); Cd^{112}-n-2n (66M51); Cd-e^--e^- (37W45b); Cd^{110}-n-γ (18G48a, 52M51); fission U (5N40a, 5N40b); spall-fission U (6F51); parent Cd^{111m_1} (20D50, 52M51); daughter (0.01%) In^{111} (66M51a)
Cd^{111m_1}	A genet (20D49a)		IT (20D49a)	8 x 10^{-8} s delay coinc (20D50, 63B50, 52M51); 10 x 10^{-8} s delay coinc (13E51c)		0.247 scint spect (52M51)		daughter Cd^{111m_2} (20D50, 52M51); daughter In^{111} (20D49a, 63B50); daughter Ag^{111} (13E51c)
Cd^{111}		12.75 (28L48)					Cd^{111}, I = 1/2 (87M50)	
Cd^{112}		24.07 (28L48)					Cd^{112}, I = 0 (87M50)	
Cd^{113m}	A chem, excit (44G49); chem, excit, sep isotopes (60C50, 59C51)		β^- (60C50)	5.1 y (60C50)	0.59 scint spect (59C51); 0.5 abs (60C50)		 (18G52)	Cd-d-p (60C50); Cd-n-γ or Cd-n-n (60C50); Cd^{112}-d-p (60C50); Cd^{112}-n-γ (59C51); fission U^{235} (1W52)
Cd^{113}		12.26 (28L48)					Cd^{113}, I = 1/2 (87M50)	
Cd^{114}		28.86 (28L48)					Cd^{114}, I = 0 (87M50)	

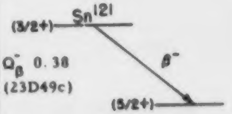
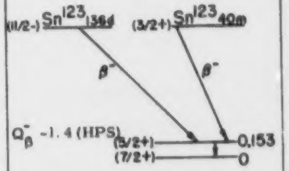
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{48}Cd^{115m}$	A chem (10C39); chem, excit (2S47b); chem, sep isotopes, n-capt (10C50b)		β^- (10C39)	43 d (2S47b, 10C50b); 44 d (33G51h)	1.61 (~98%), 0.7 (~2%), ~0.3 (weak) spect (61H52a); 1.5 abs (2S47b, 10C50b, 1W52); 1.4 abs; 0.4 (coinc with γ, ~1%) β-γ coinc abs (47G50) 1.7 abs (33G51h); ~0.8 (~1.4%) abs (13E51d)	0.46, 0.50, 0.96, 1.28 scint spect, γ-γ coinc (61H52a); γ_1 0.48, γ_2 0.94 (coinc with γ_1), γ_3 1.36 (not coinc with γ_1 or γ_2) ($\gamma_1/\gamma_2/\gamma_3$ ≈13/100/40) scint spect, γ-γ coinc (13E52) others (56G49, 52M51)	Q_β^- 1.63 (61H52a)  Cd115m Cd115 (11/2-) (1/2+) 0.18 0 β- (9/2+) 1.30 (7/2+) (3/2+) 0.95 0.860 (5/2+) 0.500 (1/2-) In115m 0.335 (9/2+) 0	Cd-d-p (10C39); Cd-n-γ (2S47, 2S47b); Cd^{114}-n-γ (10C50b); Cd^{116}-γ-n (1W52); In-n-p (2S47b); spall Sb (37L50); spall-fission Bi (11G49), Th (7N49a), U (6O48, 6F51); fission Th (21T51), U (67M51), U^{233} (61S48), U^{235} (1W52), Pu (33G51h, 28F51); daughter (9%) Ag^{115} (1W52)
Cd^{115}	A chem (10C37); chem, genet (18G38); chem, sep isotopes, n-capt (10C50b)		β^- (10C37)	53 h (1W52); 54 h (10C50b); 56 h (24L40, 67M51a)	1.11 (58%), 0.58 (42%) spect (10L52); 1.11 (~60%), 0.59 (~40%) spect (61H52a); ~1 (~85%), ~0.5 (~15%) β-γ coinc abs (1W52); others (26M49a, 10C50b, 67M51a)	0.335 (with In^{115m}), 0.360, 0.500, 0.525 scint spect, γ-γ coinc (61H52a); 0.522 spect (28D50); 0.336, 0.344, 0.349, 0.363 (?), 0.369, 0.424, 0.452, 0.525, 0.559, 0.713 spect conv (10C50b); with In^{115m}: 0.334 (10L52, 24L40, 61H49, 61H52a, 28D50, 20K51)	Q_β^- 1.45 (61H52a) (18G52)	Cd-d-p (10C37, 10C39); Cd-n-γ (18G38, 14M37, 2S47); Cd^{114}-n-γ (10C50b); Cd-n-2n (18G38); Cd-γ-n (60M48); In-n-p (2S47b); spall Sb (37L50); spall-fission Th (7N49a), U (6O48, 6F51); fission Th (21T51), U^{233} (61S48), U^{235} (1W52), U (5N40a, 5N40b, 67M51a); parent In^{115m} (18G38, 10C39, 5N40b, 67M51a, 1W52, 10L52); daughter (91%) Ag^{115} (1W52)
Cd^{116}		7.58 (28L48)					Cd^{116}, I = 0 (87M50)	
Cd^{117m}	A chem, excit (10C39)		IT (51C52a)	3.0 h (51C52a); 2.9 h (25A52); 2.8 h (24L40); 2.7 h (67M51b)		with Cd^{117} (51C52a): ~1.2 abs (25A52)		Cd-d-p (10C39, 51C52a, 25A52); Cd-n-γ (14M37, 18G38, 2S47, 51C52a); spall-fission U (6F51); fission U (5N40a, 5N40b, 67M51b); parent In^{117} (18G38, 24L40, 67M51b), via Cd^{117} (51C52a)
Cd^{117}	A chem, genet (51C52a)		β^- (51C52a)	~50 m (51C52a)	~1.6, ~3.0 abs (51C52a)			Cd-n-γ, Cd-d-p, parent In^{117}, parent In^{117m} (51C52a)
$_{49}In^{107}$	A chem, sep isotopes (68M49); mass spect (97M52)		β^+ (68M49)	30 m (97M52); 33 m (68M49)	~2 spect (68M49)			Cd^{106}-p-γ, Cd^{106}-d-n (68M49)
In^{108}	A chem, sep isotopes (68M49); mass spect (97M52)		β^+ (68M49)	50 m (97M52, 66M51); ~55 m (68M49)	2.31 spect (66M51); 2.2 abs (37L50); ~2 spect (68M49)	0.285 (<5%, K/L ≥3) spect conv (66M51)	Q_β^+ 3.3 (66M51)	Cd^{108}-d-2n (68M49); daughter Sn^{108} (68M49, 37L50, 66M51)
In^{109}	A chem, excit (25T47); chem, mass spect (48G48); chem, excit, sep isotopes (68M49)		β^+, EC (25T47, 68M49)	4.3 h (68M49); 4.2 h (66M51); 6.5 h (25T47); 5.2 h (48G48)	0.75 abs (68M49); ~2 (weak) (25T47)	0.427, 0.347, 0.205 (K/L 3), 0.058 (K/L 0.9) spect conv (66M51)		Ag-α-2n (25T47, 48G48, 66M51); Cd^{106}-α-p, Cd^{108}-d-n, Cd^{108}-p-γ (68M49)

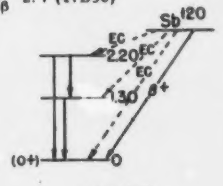
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{49}In^{110m}$	A chem (48G48); chem, genet energy levels Ag^{110} (66M51a, 35B51)		EC 99+%, IT -0.3% (66M51)	5.0 h (66M51); 4.9 h (35B51); -5 h (48G48)		0.119 (with IT, K/L 4.5), 0.935, 0.885, 0.661 spect conv (66M51); 0.119 (weak), 0.937, 0.887, 0.654 spect conv (35B51)	 In^{110m} 0.119 In^{110} 0 EC EC, β^+ 2.48 1.54 (1,2+) 0.65 (0+) 0	Ag-a-3n (48G48, 66M51)
In^{110}	A chem (58B39); chem, excit, mass spect (48G48)		β^+, EC (61C49)	66 m (58B39, 35B51); 65 m (48G48)	2.25 spect (61C49)	0.654 spect conv (35B51); 0.677 (e/γ 0.005) spect, spect conv (61C49)	see Ag^{110} Q_{β}^{+} 3.92 (61C49) (35B51, 61C49, 18G52)	Ag-a-n (19K39a, 25T47a, 48G48); Cd-p-n (58B39); Cd-d-2n (24L40)
In^{111}	A chem (10C39); chem, excit (25T47a, 48G48); mass spect (48G48)		EC (24L40); no β^+ (lim 0.06%) (66M51); no β^+ (48G48)	2.84 d (66M51); 2.7 d (58B39, 10C39)		0.172 (-100%, e/γ 0.12, K/L 6.6), 0.247 (-100%, e/γ 0.064, K/L 5.19), 0.330 (weak), 0.093 (weak) spect, spect conv, conv-conv coinc abs (66M51); 0.173 (e/γ 0.09, K/L -8), 0.247 (e/γ 0.04, K/L -5) γ-conv, conv-conv, γ-γ coinc (56B49); 0.171 (K/L+M 7.03), 0.246 (K/L+M 4.79) spect conv (59G52); 0.173 (K/L+M 6.6), 0.247 (K/L+M 5.3) spect conv (34H52); 0.173 (K/L 6.6), 0.247 (K/L 5.4) spect conv (24L40); 0.25 (coinc with 0.17 γ) scint spect, γ-γ delay coinc (69M51); others (36A51, 36A51a)	see Ag^{111}  In^{111} (9/2+) ~100% EC 0.01% (7/2+) 0.419 Cd^{111m_2} (11/2-) 0.393 (3/2+) 0.340 ~100% Cd^{111m_1} (5/2+) 0.247 ~100% (1/2+) 0 (66M51, 66M51a)	Ag-a-γ (112S51); Ag-a-2n (24L40, 25T47a, 48G48, 66M51); Cd-p-n (58B39); Cd-a-p (66M51); Cd-d-n (24L40); In-n-3n (10C39); spall Sb (37L50); parent (0.01%) Cd^{111m_2} (66M51a); parent Cd^{111m_1} (20D49a, 63B50)
In^{112m}	A chem (58B39); chem, cross bomb, excit (81S42); chem, excit (25T47a)		IT (81S42, 25T47a)	20.9 m (35B52); 20 m (58B39); 23 m (25T47a)		0.154 (e/γ >4) spect conv (61C49); 0.16 spect conv (58B39); 0.16 (e/γ large) abs (25T47a)	 In^{112m} (4±) 0.154 In^{112} (1+) 0 β^- (0+) β^+,EC (0+)	Ag-a-n (81S42, 25T47a); Cd-d-n (24L40); Cd-p-n (58B39); In-n-2n (81S42, 25T47a); parent In^{112} (81S42, 25T47a, 49G50)
In^{112}	A chem, cross bomb, excit (81S42); chem, excit (25T47a)		β^-, β^+, EC (25T47a, 61C49); β^-/β^+ 2.7 (61C49)	14.5 m (35B52)	β^+: 1.74 spect (61C49); 1.7 spect (24L40) β^-: 0.67 spect (61C49)		(18G52)	Ag-a-n (81S42, 25T47a); In-n-2n (81S42, 25T47a); daughter In^{112m} (81S42, 25T47a, 49G50)

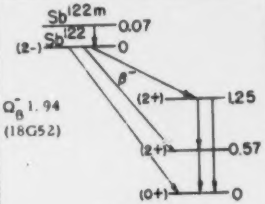
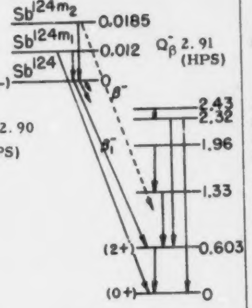
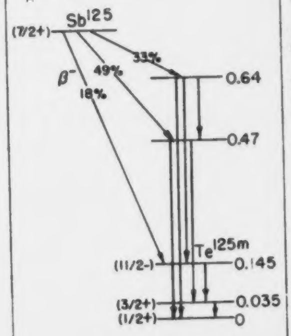
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{49}In^{m}$	E (31K52)		IT (31K52)	2.5 s (31K52)		0.153 scint spect (31K52)		In^{113}-n (31K52)
In^{113m}	A chem, excit, genet (58B39)		IT (58B39)	104 m (24L40) 105 m (58B39)		0.392 (K/L+M 4.21) spect conv (59G52); 0.393 spect conv (10C51a); 0.39 spect conv (58B39); 0.39 (K/L 5.4) spect conv (24L40); 0.39 (e/γ 0.55) scint spect (62C52); ~0.39 (e/γ 0.35, K/L 5.4) spect conv, ion ch (26T51)	 (18G52)	Cd-p-n (58B39); Cd-d-n (24L40); In-n-n (63C48); In-γ-γ (11D47); daughter Sn^{113} (58B39, 24S40a)
In^{113}		4.23 (24W48)					In^{113}, I = 9/2 (67M50)	
In^{114m}	A chem, n-capt, excit (24L37, 14M38)		IT, no EC (82S52)	49 d (58B39)		γ_1 with In^{114m}, γ_2, γ_3, γ_4, γ_5, γ_6 with In^{114}; γ_1 0.190, γ_2 0.552, γ_3 0.722, γ_4 1.27 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 100/18.6/18.6/1.2) spect (53M49); γ_1 0.192 (e/γ 4.2, K/L 1.10) spect conv, scint spect (82S51); γ_1 0.190 (K/L/M = 1.18/1.00/0.18) spect conv (59G52); γ_1 0.191 spect conv (10C48); γ_1 (K/L 1.30) spect conv (40K52); γ_1 0.192 (e/γ 4, K/L 1.1), γ_2 0.55, γ_3 0.72 spect conv (56B49a); γ_1 (e/γ 4) spect conv (10L49a); γ_1 (K/L 1.16) spect conv (88S51a); γ_4/γ_2 ~0.06 scint spect, γ-γ coinc (23K52); γ_5 0.576, γ_6 1.30 (coinc with γ_2) spect, γ-γ coinc (25J52)	 In^{114m} (5+) 0.190 In^{114} (1+) 0 1.85 EC (2+) 1.27 β⁻ β⁺,EC (2+) 0.552 (0+) 0 (0+) (HPS, 18G52,25J52)	Cd-p-n (58B39); Cd-d-n (24L40, 46M49); In-n-γ (24L37, 14M38, 46M49); In-d-p (24L40); In-γ-n (25W48, 22E52); In-n-2n (24L40); spall Sb (37L50); parent In^{114} (49G50)
In^{114}	A excit (7C37, 37B37a, 24L37); n-capt, sep isotopes (18G48a)		β⁻ ≤97%, EC ≥3%, β⁺ ~0.01% (82S52); β⁻ 99+%, β⁺ 0.015% (25J52); β⁻ 99+%, β⁺ ~0.01% (56B49a)	72 s (24L37, 58B39)	β⁻: 1.984 spect (25J52); 1.98 spect (24L40); 2.01 spect (88S51a); 2.05 abs (46M49) β⁺: ~1 abs (25J52); 0.65 spect (56B49a)		Q_{β}^{-} 1.98 (25J52) Q_{β}^{+} 2.07 p-n threshold (66M51)	Cd-p-n (58B39); In-n-2n (24L37, 1P37); In-γ-n (37B37a, 7C37, 25W48, 22E52); In^{113}-n-γ (18G48a); daughter In^{114m} (49G50)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{49}\text{In}^{115m}$	A chem, excit (18G38)		IT (24L39), β^- (11B49); IT 95%, β^- 5% (10L52)	4. 50 h (11D47); 4. 53 h (24L40)	0. 83 spect (11B49)	0. 335 (e/γ 0. 98, K/L+M 3. 76) spect conv (10L52, 59G52); 0. 338 (e/γ ~1, K/L 5. 0, K/L+M 4. 0) spect conv (24L40); 0. 335 (K/L 5. 3) spect conv (20K51); 0. 337 spect, spect conv (61H49); 0. 336 spect (28D50)	Q_β^- 0. 83 (HPS)  (1/2-) In^{115m} 0.334 (9/2+) In^{115} 0 β^- (1/2+) (18G52)	Cd-d-n (24L40); In-n-n (18G38, 63C48); In-p-p (58B39, 58B39a); In-α-α (38L39); In-e-e (64C40, 41W43, 41W49); In-γ-γ (17P38a, 64C39, 70M49, 83S51); fission Th (21T51), U (5N40a); daughter Cd^{115} (18G38, 10C39, 5N40b, 67M51a, 1W52, 10L52)
In^{115}	A chem, sep isotopes (71M50)	95. 77 (24W48)	β^- (71M50, 63C51)	6 x 10^{14} y sp act (71M50); ~10^{14} y sp act (63C51)	0. 63 abs (71M50)		Q_β^- 0. 5 calc (11B49) In^{115}, I = 9/2 (87M50)	natural source (71M50)
In^{116m}	A chem, n-capt (12A35); chem, excit, n-capt (24L37)		β^- (24L37)	53. 93 m (57S49); 54. 31 m (38R50); 54. 05 m (50G47)	1. 00 (51%), 0. 87 (28%), 0. 60 (21%) spect, β-γ coinc (5S50); 0. 85 spect (10C39); cl ch (48C40); 0. 7 β-γ coinc abs (26M48d)	2. 090 (25%), 1. 487 (21%), 1. 274 (75%, e/γ 5. 7 x 10^{-4}), 1. 085 (54%, e/γ 8. 4 x 10^{-4}), 0. 406 (25%), 0. 137 (3%) spect conv (5S50); 0. 137, 0. 171 spect conv (11K50a); others (20D42c, 48C40, 24L40, 18J45, 42W47)	Q_β^- 3. 36 (5S50)  In^{116m} 0.4 (1+) In^{116} 28% 0 21% 51% β^- 2.76 2.50 2.36 2.09 1,27 (0+) 0 (5S50, 18G52)	Cd-p-n (58B39); In-n-γ (12A35, 14M38a, 34G46, 2S47, 50H51); In-d-p (24L37)
In^{116}	A n-capt (12A35); excit, n-capt (24L37)		β^- (24L37)	13 s (12A35, 10C39)	2. 95 abs (35B46a, calc from 24L40); 2. 8 cl ch (10C39)	no γ (14M38a)	Q_β^- 2. 95 (HPS)	Cd-p-n (2D40); In-n-γ (12A35, 24L37, 34G46, 2S47); In-d-p (24L37); Sn-γ-p (42H47)
In^{117m}	A chem, genet (51C52a)		IT, β^- (51C52a)	~70 m (51C52a)	see In^{117}			daughter Cd^{117} (51C52a)
In^{117}	A chem, excit (10C39)		β^- (10C39)	~2. 5 h (51C52a); 1. 95 h (24L40); 1. 90 h (67M51b)	with In^{117m} (?) (51C52a): 1. 726 spect (20K51); 1. 73 spect (10C39); 1. 95 abs (67M51b) with In^{117}: 0. 7 abs (51C52a)	0. 161, 0. 558 scint spect (20K51)		Cd-d-n (10C39, 24L40); Sn-γ-p (42H47); fission U (5N40a, 5N40b, 67M51b), Pu (32K48); daughter Cd^{117m} (18G3 24L40, 67M51b); daughter Cd^{117} (51C52
In^{118}	B excit, sep isotopes (23D49b)		β^- (23D49b)	4. 5 m (23D49b)	1. 5 abs (23D49b)	γ (23D49b)		Sn^{119}-γ-p (23D49b)
In^{119}	B chem, excit, sep isotopes (23D49b)		β^- (23D49b)	17. 5 m (23D49b)	2. 7 abs (23D49b)	no γ (23D49b)		Sn^{120}-γ-p (23D49b)

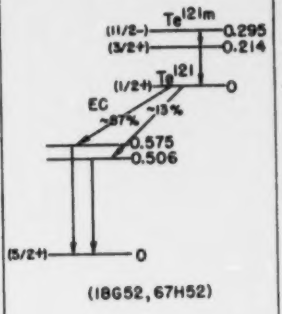
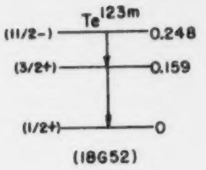
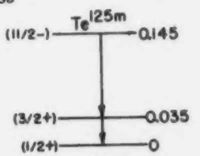
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{50}$Sn^{108}	B chem, sep isotopes (68M49)		EC (68M49)	4.0 h (66M51); 4.5 h (68M49)				Cd^{106}-α-2n (68M49); Cd-α-2n (66M51); parent In^{108} (68M49, 37L50, 66M51); spall Sb (37L50)
Sn^{111}	B chem, sep isotopes (66H49)		EC ~71%, β^+ ~29% (66M51)	35.0 m (66H49); 35 m (66M51)	1.51 spect (66M51); 1.5 abs (66H49)			Cd-α-3n (66M51); Cd^{108}-α-n (66H49)
Sn^{112}		0.95 (1B50)						
Sn^{113}	A chem, excit (58B39, 12L39c)		EC, no β^+ (58B39); EC (L/K ~0.8) (26T51)	112 d (19N50); 118 d (10C51a); 105 d (58B39)		with In^{113m}: 0.393 (10C51a, 58B39, 24L40, 62C52, 26T51); 0.401 (weak), 0.255 (weak) spect conv (10C51a); no 0.09 γ (65C47, 26T51, 10C51a, 63M51a, 28B51)	Q_{EC} 0.43 calc (26T51)  Sn^{113} EC (1/2-) In^{113m} 0.393 (9/2+) In^{113} 0 (HPS)	Cd-α-n (12L39c); In-p-n (58B39); In-d-2n (65C47); Sn d-p (12L39c); Sn-γ-n (60M48); Sn-n-γ (2S47, 28B51); Sn^{112}-n-γ (19N50, 63M51a, 10C51a); spall Sb (37L50); parent In^{113m} (58B39, 24S40a)
Sn^{114}		0.65 (1B50)						
Sn^{115}		0.34 (1B50)					Sn^{115}, I = 1/2 (87M50)	
Sn^{116}		14.24 (1B50)					Sn^{116}, I = 0 (87M50)	
Sn^{117m}	A chem (12L39c); chem, sep isotopes, cross bomb (68M50)		IT (68M50)	14.0 d (10C51a); 15 d (19N50)		0.159 (e/γ very large, K/L 2.2), 0.162 (e_K/γ 0.10) spect conv, e-γ coinc, x-γ coinc (63M50); 0.156 (e/γ large, K/L ~7), 0.159 spect conv (10C51a); 0.157 (K/L 2.2) spect conv (61H50a); 0.152 (K/L 2.4) spect conv (19N50)	 Sn^{117m} (11/2-) 0.321 (3/2+) 0.162 (1/2+) 0 (63M50, 18G52)	Cd^{114}-α-n (68M50); Cd-α-n (12L39c); Sn^{116}-n-γ (63M50, 19N50); Sn^{116}-d-p, Sn^{118}-n-2n (68M50); Sn^{117}-n-n (68M50, 19N50); spall Sb (37L50)
Sn^{117}		7.57 (1B50)					Sn^{117}, I = 1/2 (87M50)	
Sn^{118}		24.01 (1B50)					Sn^{118}, I = 0 (87M50)	
Sn^{119m}	A chem, n-capt, sep isotopes (63M50)		IT (63M50)	~250 d (63M50); ~245 d (19N50)		γ_1 0.0653 (K/L 0.51, L/M ~4), γ_2 0.0242 (L/M ~4) spect conv (67H51); γ_2 0.0238 (e/γ ~7) scint spect, ion ch, γ-γ coinc (28B51); γ_1 0.065, γ_2 0.024 scint spect, ion ch conv (17S51b); γ_1 0.064 (K/L 0.82) spect conv (19N50)	 Sn^{119m} (11/2-) 0.089 (3/2+) 0.024 (1/2+) 0 (17S51b, 28B51, 18G52)	Sn^{118}-n-γ (63M50, 19N50, 17S51b, 28B51)
Sn^{119}		8.58 (1B50)					Sn^{119}, I = 1/2 (87M50)	
Sn^{120}		32.97 (1B50)					Sn^{120}, I = 0 (87M50)	

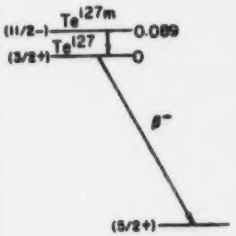
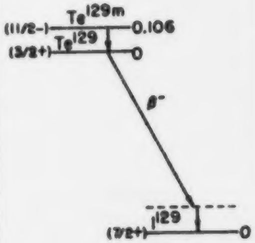
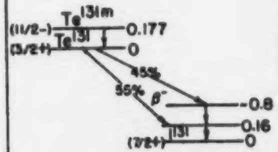
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{50}Sn^{121m}$	E sep isotopes, n-capt (19N50)		β^- (19N50)	>400 d (19N50)	0.42 spect (19N50)			Sn^{120}-n-γ (19N50)
Sn^{121}	A chem, excit (12L39c); chem, sep isotopes (37L48a)		β^- (12L39c)	27.5 h (19N50); 28 h (23D49c); ~27 h (6F51)	0.383 spect (23D49c); 0.4 abs (37L48a); 0.35 abs (39L49)	no γ (23D49c, 37L48a, 7N49b); others (52M51)	 Q_β^- 0.38 (23D49c) (18G52)	Sn-d-p (12L39c); Sn-n-γ (12L39c, 2S47); Sn^{120}-d-p (37L48a, 39L49, 7N49b); Sn^{120}-n-γ (39L49, 23D49c, 19N50); Sn^{122}-n-2n (39L49); Sb-d-α (37L50); spall-fission Th (7N49a), U (6O48, 6F51)
Sn^{122}		4.71 (1B50)						
Sn^{123}	A chem (12L39c); chem, sep isotopes, excit (7N49b, 39L49, 19N50)		β^- (12L39c)	39.5 m (23D49c); 40 m (12L39c, 39L49, 19N50); 41.5 m (60M48); 39 m (7N49b)	1.26 spect (23D49c); 1.3 abs (39L49); 1.1 abs (19N50)	0.153 spect conv, β-e coinc (23D49c); 0.153 scint spect (76B51c); others (52M51)	Q_β^- ~1.4 (HPS)  (11/2-) Sn^{123} 136d (3/2+) Sn^{123} 40m β^- β^- (3/2+) (7/2+) 0.153 0 (18G52)	Sn-d-p (12L39c); Sn-n-γ (2S47); Sn-n-2n (1P37); Sn-γ-n (60M48, 7H49); Sn^{124}-d-t (7N49b); Sn^{122}-n-γ (23D49c, 39L49, 19N50); Sn^{124}-n-2n (39L49)
Sn^{123}	A chem (40L46, 40L51); chem, sep isotopes, cross bomb (39L49)		β^- (40L51)	136 d (38G51); 125 d (10C51a); 130 d (39L49, 7N49b, 40L51); 126 d (19N50)	1.42 spect (24K50b); 1.3 abs (39L49)	no γ (39L49, 7N49b, 19N50, 10C51a, 38G51)	Q_β^- ~1.4 (HPS)	Sn^{122}-n-γ (39L49, 19N50); Sn^{122}-d-p, Sn^{124}-n-2n (39L49); Sn^{124}-d-t (7N49b); Sb-n-p (7N49b); spall-fission Th (7N49a), U (6F51); fission U (38G46, 40L51), U^{233} (38G48, 38G51), U^{235} (38G51)
Sn^{124}		5.98 (1B50)		double β^- decay: (lower limit, by sp act) >2 x 10^{17} y (41K52, 32F52, 70H52); >10^{17} y (72M52); >10^{16} y (41L51, 25P52)				
Sn^{125}	A chem, excit, n-capt (12L39c); chem, sep isotopes (23D50a, 39L49, 19N50)		β^- (12L39c)	9.5 m (19N50); 9.8 m (39L49)	2.04, 1.17, 0.51 (?) spect (23D50a); 2.06, ~0.5 abs (19N50)	0.326, others >1 (weak) spect, spect conv (23D50a); 0.38 (coinc with 2.06 β) abs, β-γ coinc (19N50); 1.37 (weak) scint spect (76B51c)	Q_β^- ~2.4 (HPS)	Sn-d-p (12L39c); Sn-n-γ (12L39c, 23S47, 2S47); Sn^{124}-n-γ (39L49, 23D50a, 19N50)
Sn^{125}	A chem (12L39c); chem, excit, sep isotopes (39L49); chem, sep isotopes, n-capt, genet (19N50)		β^- (12L39c)	9.4 d (19N50); 10.0 d (39L49); 9.5 d (7N49b)	2.37 (~95%), 0.40 (~5%) spect (61H50b); 2.33 spect (24K50b); ~0.5 (10%) β-γ coinc abs (26M52a); others (65C47, 7N49b, 39L49, 77S51a)	1.90 scint spect, abs (76B51d); 1.67 coinc abs sec (26M52a)	Q_β^- ~2.4 (HPS)	Sn-n-γ (12L39c, 2S47); Sn-d-p (12L39c, 65C47); Sn^{124}-n-γ (39L49, 19N50); Sn^{124}-d-p (39L49); spall-fission Th (7N49a), U (6F51); fission U^{233} (61S48, 38G51), U (16H43b, 77S51a), U^{235} (38G51); parent Sb^{125} (19N50); not parent Sb^{125} (7N49b)

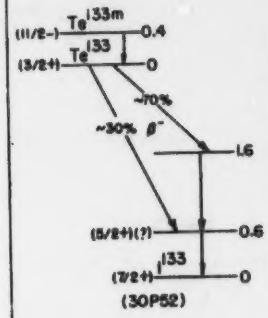
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{50}Sn^{126}$	B chem, genet (80B51)		β^- (80B51)	~50 m yield (80B51)				fission U^{235}, parent Sb^{126} (80B51)
Sn^{127}	A chem, genet (80B51)		β^- (80B51)	1.5 h yield (80B51)				fission U^{235}, parent Sb^{127} (80B51)
$_{51}Sb^{116}$	A chem, excit, mass spect (27T49)		β^+ (27T49)	60 m (27T49)	~1.45 spect (27T49)			In-α-3n (27T49)
Sb^{117}	A chem (12L39d); chem, excit, mass spect (27T49)		EC (65C47)	2.8 h (65C47, 27T49)		0.156 spect conv (27T49)		In-α-2n (27T49); Sn-d-n (12L39d, 65C47); Sn-p-n (65C47); spall I (π) (51Y52)
Sb^{118}	B excit (27R40)		β^+ (37L48a)	3.5 m (37L48a); 3.6 m (27R40)	3.1 abs, spect (37L48a)			In-α-n (38L39, 27R40); Sn-p-n (2D40); daughter Te^{118} (37L48a)
Sb^{118}	A chem, cross bomb (65C47); chem, excit, mass spect (27T49)		EC (65C47)	5.1 h (65C47, 27T49)	e ~0.2 abs (65C47)	0.260 spect conv (27T49); 1.5 abs (65C47)		In-α-n (65C47, 27T49); Sn-d-n (65C47)
Sb^{119}	B chem, cross bomb (65C47)		EC (65C47)	39 h (65C47, 37L48a)		no γ (65C47); Sn K-x (65C47, 37L48a)		Sn-d-n, Sn-p-n (65C47); spall Sb (37L48a); daughter Te^{119} (37L48a)
Sb^{120}	D chem, sep isotopes (37L48a)		EC'(37L48a)	6.0 d (37L48a)		~1.1 abs (37L48a)		Sb-d-p2n (37L48a); Sn^{120}-d-2n (37L48a); spall-fission Bi (11G49); not found: Sn-p, Sb-γ (47B51); Sb-x rays (30K51a)
Sb^{120}	A chem, excit (37B39, 6H37, 7C37); chem, excit, cross bomb (12L37a)		β^+, EC (47B50)	16.4 m (22J50); 16.6 m (12P48); 17 m (6H37, 12L39d)	1.70 spect (47B50)	γ_1 0.90, γ_2 1.30, γ_3 2.20 ($\gamma_1/\gamma_2/\gamma_3$ ~ 0.08/0.35/0.04) (e/γ very small) spect (47B50)	Q_β^+ 2.7 (47B50)  (47B50)	Sn-d-n (12L39d); Sn-p-n (47B50); Sn^{120}-d-2n (37L48a); Sb-n-2n (1P37, 6H37, 21J44, 7C37); Sb-γ-n (37B39, 12P48, 27M49, 25W48, 22J50); Sb-d-t (9K41a); Sb-p-pn (23R46)
Sb^{121}		57.25 (24W48)					Sb^{121}, I = 5/2 (87M50)	

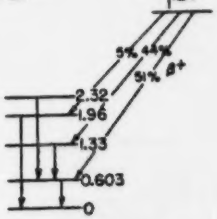
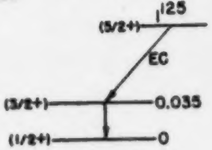
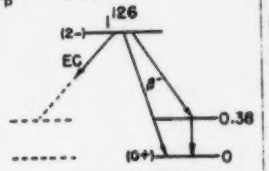
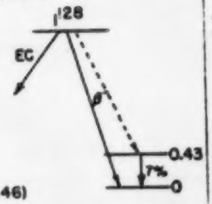
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{51}Sb^{122m}$	A chem, n-capt, sep isotopes (38M47)		IT (38M47)	3.5 m (38M47)		0.068 scint spect (38M51); 0.059, 0.074 ion ch (31K51)	 Sb^{122m} 0.07 Sb^{122} (2-) 0 β^- (2+) 1.25 (2+) 0.57 (0+) 0	Sb-n-γ (38M47); Sb^{121}-n-γ (38M51, 31K51)
Sb^{122}	A chem (12A35); chem, cross bomb (12L39d)		β^- (12L39d)	2.80 d (47B51); 2.8 d (12L39b)	β_2 1.46 (coinc with γ) β-γ coinc spect (23M51); β_1 1.94, β_2 1.36 spect (43M46); β_1 1.8, β_2 1.2 abs, coinc abs (26M48d); β_1 1.8 abs (14M40)	0.568 spect (28C48d, 28K48); 0.57 spect conv (11R47); 0.56 (e_K/γ 0.0049), 0.68 (51G52)	Q_β^- 1.94 (18G52) (18G52)	Sn-d-2n (12L39d); Sn-p-n (47B51); Sb-d-p (12L39d); Sb-γ-n (22J50, 47B51); Sb-n-γ (12A35, 12L39d, 2S47, 50H51); spall Sb (37L50), I (w) (51W52); spall-fission Bi (11G49)
Sb^{123}		42.75 (24W48)					Sb^{123}, I = 7/2 (87M50)	
Sb^{124m_2}	A chem, n-capt, sep isotopes (38M47)		IT, β^- (38M47)	21 m (38M47)		0.0185 (e/γ very large) (18G50)	Q_β^- 2.92 (HPS)  Sb^{124m_2} 0.0185 Sb^{124m_1} 0.012 Sb^{124} (3-) 0 β^- β_1^- 2.43 2.32 1.96 1.33 (2+) 0.603 (0+) 0	Sb-n-γ, Sb^{123}-n-γ (38M47)
Sb^{124m_1}	A chem, n-capt, sep isotopes (38M47)		IT, β^- (38M47)	1.3 m (38M47)	3.2 abs (38M47)	0.012 (e/γ very large) (18G50)	Q_β^- 2.91 (HPS)	Sb-n-γ, Sb^{123}-n-γ (38M47)
Sb^{124}	A chem (12L37a); chem, excit, cross bomb (12L39d)		β^- (12L39d); no β^+, no EC (10L50b)	60 d (12L39d)	β_1 2.291 (21%), β_2 1.69 (7%), β_3 0.95 (7%), β_4 0.68 (26%), β_5 0.50 (39%) spect (28C48d, 10L50b); β_1 2.37 21%), β_2 1.62 (8%), β_3 1.00 (9%), β_4 0.65 (44%), β_5 0.48 (18%) spect (28K48); β_4 0.654 pect (7J47); others (54H43 47M47, 43M46, 14M40, 37W47)	0.121, 0.[illegible]7, 0.653, 0.730, 1.708, 2.04 spect, spect conv (28C48d, 10L50b); 0.61 γ (40-50%, e_K/γ 0.0043) spect, spect conv (44M52a); 0.61 γ (e_K/γ 0.0036) spect conv (94H52); 0.603 (-100%, e/γ -0.002), 0.650, 0.714, 1.708, 2.06 spect, spect conv (28K48); 0.598, 0.645, 0.817, 1.67, 2.07 spect (13J49b); others (11R47, 14M40, 42W47, 52M51, 85S51, 89S52, 39D51, 39D51a, 42K45, 47M47)	Q_β^- 2.90 (HPS) (18G52, HPS)	Sn p-n (47B51); Sn-d-2n (12L39d); Sb-d-p (12L39d, 54H43, 42K45); Sb-n-γ (12L39d, 2S47); spall Sb (37L50); Te-d-α (28T38); I-n-α (12L39d); spall-fission Bi (11G49)
Sb^{125}	A chem (12L39d); chem, n-capt (84S51)		β^- (67C51)	~2.7 y (40L51a)	0.616 (18%), 0.299 (49%), 0.128 (33%) spect (7S49d); 0.621, 0.28?, others (?) spect (28K49); others (38G46, 15J49, 26M49b, 84S51)	0.637, 0.601, 0.465, 0.425, 0.175, 0.035 spect, spect conv, coinc (7S49d); 0.646 (weak, e/γ very small), 0.609 (strong), 0.466 (weak, e/γ very small), 0.431 (strong), 0.174 (strong), 0.125 (weak) spect, spect conv, coinc (28K49); with Te^{125m}: 0.110, 0.035 (28B52, 10C51a, 7S49d, 28K49, 67H49a)	Q_β^- 0.76 (7S49d)  Sb^{125} (7/2+) β^- 18% 49% 33% 0.64 0.47 Te^{125m} (11/2-) 0.145 (3/2+) 0.035 (1/2+) 0 (7S49d, 18G52)	Sn-d-n (12L39d); Sn-n-γ, β^- decay (7S49d, 23F48, 84S51); spall-fission Th (7N49a); fission U^{233} (38G48), U (67C51, 40L51a, 84S51); parent Te^{125m} (23F48, 28K49); daughter (9.4 d) Sn^{125} (19N50); not daughter (9.4 d) Sn^{125} (7N49b)

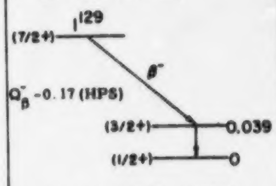
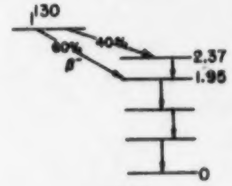
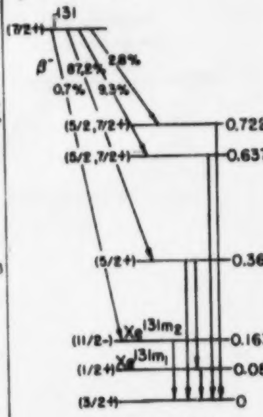
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{51}\mathrm{Sb}^{126}$	B chem, excit (80B51)		β^- (80B51)	9 h (80B51)	-1 abs (80B51)	0.90, -0.4 (both coinc with β^-) scint spect, β-γ coinc (80B51)		fission U^{235}, daughter Sn^{126} (80B51)
Sb	E chem (80B51)		β^- (80B51)	10 m (80B51)				fission U^{235} (80B51)
Sb^{-126}	D chem (38G46)		β^- (38G46)	28 d (38G46); -30 d (80B51)	1.9 (38G46)			fission U (38G46), U^{235} (80B51)
Sb^{127}	A chem, genet (32A39)		β^- (32A39)	93 h (76S51b); 95 h (38G46)	1.2 abs (76S51b); 0.8 abs (38G46)	0.72 abs (76S51b)		fission U^{233} (61S48), U^{235} (38G51, 80B51), U (32A39, 38G46, 76S51b), Pu (32K48); parent Te^{127} (32A39, 33G51i); parent (84%) Te^{127}, parent (16%) Te^{127m} (78B48); daughter Sn^{127} (80B51)
Sb^{129}	A chem, genet (32A39)		β^- (32A39)	4.2 h (32A39)				fission U (32A39), Pu (32K48); parent Te^{129} (32A39)
Sb^{130}	D chem, excit (fission yield) (80B52)		β^- (80B52)	40 m (80B52)				fission U^{235} (80B52)
Sb^{130}	D chem, excit (fission yield) (30P52a)		β^- (80B52)	12 m (30P52a); 10 m (80B52)				fission U (80B52, 30P52a)
Sb^{131}	A chem, genet (30P51, 68C51)		β^- (30P51)	23.1 m (30P51); -20 m (68C51)				fission U, parent Te^{131}, parent Te^{131m} (30P51, 68C51)
Sb^{132}	B chem, genet (32A39)		β^- (32A39)	2 m (30P51); -5 m (32A39); -2 m (68C51)				fission U (32A39, 30P51, 68C51); parent Te^{132} (32A39, 30P52a)
Sb^{133}	B chem, genet (30P51)		β^- (30P51)	4.4 m (30P51); 4.2 m (68C51)				fission U (30P51, 68C51); parent Te^{133m} (30P51)
$\mathrm{Sb}^{134,135}$	D chem (30P51)		β^- (30P51)	-50 s (30P51); 45 s (68C51)				fission U (30P51, 68C51)
$_{52}\mathrm{Te}^{<118}$	D chem (37L48a)		β^+ (37L48b)	2.5 h (37L48a)				spall Sb (37L48a), I (π) (51W52)
Te^{118}	B chem, genet (37L48a)		EC (37L48a)	6.0 d (37L48a)		no γ (?) (37L48a)		Sb-d-5n, parent (4 m) Sb^{118} (37L48a, 37L50); spall I (π) (51W52); spall-fission Bi (11G49)
Te^{119}	B chem, genet (37L48a)		EC (37L48a)	4.5 d (37L48a)	conv: 0.2, 0.5 spect conv (37L48a)	1.6 abs (37L50)		Sb-d-4n, parent Sb^{119} (37L48a, 37L50); spall-fission Bi (11G49)
Te^{120}		0.089 (1B50)						

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{52}Te^{121m}$	A chem, excit, cross bomb (13S40); chem, n-capt, sep isotopes (10C51a)		IT (14E46a)	154 d (67H51d); 143 d (14E46a); 125 d (13S40); 140 d (10C51a)		γ_1 0.082 (e/γ very large, K/L 0.75), γ_2 0.213 (e_K/γ 0.09, K/L 7.3) (γ_2 coinc with γ_1) spect conv, conv-γ coinc, conv-conv coinc (43K50); γ_1 0.0818, γ_2 0.214 spect conv (10C51a): others (67H49, 81B46, 82B46, 6Y45, 20D50, 4K42a)	 (11/2-) (3/2+) Te121m 0.295 0.214 (1/2+) Te121 0 EC ~87% ~13% 0.575 0.506 (5/2+) 0 (18G52, 67H52)	Sn-α-n (13S40); Sb-d-2n (13S40, 14E46a, 43K50); Sb-p-n (13S40, 14E46a); spall Sb (37L50); Te^{120}-n-γ (10C51a); parent Te^{121} (82B46)
Te^{121}	A chem, genet (14E46a, 82B46)		EC (14E46a)	17 d (14E46a); ~16 d (82B46)		γ_1 0.506 (13%, e/γ ~0.018, K/L+M 6), γ_2 0.573 (87%, not coinc with γ_1, e/γ 0.009, K/L+M 6) spect conv, scint spect (67H52); 0.575 spect conv (10C51a); ~0.61 (e_K/γ 0.004) spect conv (43K50); 0.6 abs (14E46a)		Sb-d-2n (14E46a); Sb-p-n (14E46a); daughter Te^{121m} (82B46); daughter I^{121} (74M50)
Te^{122}		2.46 (1B50)						
Te^{123m}	A chem, n-capt, sep isotopes (67H49)		IT (67H49)	104 d (67H51d); 121 d (10C51a)		γ_1 0.0885 (e/γ very large, K/L 0.68), γ_2 0.159 (e_K/γ 0.18, K/L 8.9) (γ_1 coinc with γ_2) spect conv, γ-conv coinc, conv-conv coinc, abs (43K50); γ_1 0.0887, γ_2 0.159 spect conv (10C51a); γ_1 (L_I/L_{III} 0.5) spect conv (63M52a); γ_2 (e_K/γ 0.19) scint spect (52M52e); no 0.25 γ (lim 0.5%) scint spect (68H51); others (4K42a, 67H49, 20D50, 52M52)	 Te123m (11/2-) 0.248 (3/2+) 0.159 (1/2+) 0 (18G52)	Sb-d-2n (43K50); Te^{122}-n-γ (67H49, 43K50, 68H51, 10C51a)
Te^{123}		0.87 (1B50)					Te^{123}, I = 1/2 (87M50)	
Te^{124}		4.61 (1B50)						
Te^{125m}	A chem, genet (23F48)		IT (23F48)	58 d (67H49a, 67H51d)		0.110 (e_K/γ ~160, K/L+M 1.15), 0.0355 (e_K/γ ~11.7, K/L/M = 7.3/1.0/0.18) spect conv, ion ch, scint spect, x-γ coinc, x-x coinc (28B52); 0.110, 0.0353 spect conv (10C51a); 0.110 (K/L+M 1.1), 0.035 spect conv (7S49d); 0.110 (K/L 1.2) spect conv (28K49); 0.109 (e/γ >100, K/L ~1.5, L/M ~3.5) spect conv (67H49a); others (67H49, 23F50a, 52M51, 28B49)	see Sb^{125}  Te125m (11/2-) 0.145 (3/2+) 0.035 (1/2+) 0 (28B52)	Te^{124}-n-γ (67H49); daughter Sb^{125} (23F48, 28K49); not daughter I^{125} (lim 0.05%) (23F51b)
Te^{125}		6.99 (1B50)					Te^{125}, I = 1/2 (87M50)	
Te^{126}		18.71 (1B50)					Te^{126}, I = 0 (87M50)	

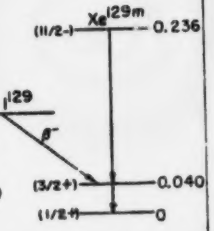
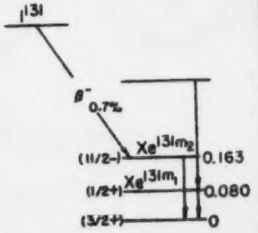
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{52}$Te^{127m}	A chem, excit, genet (13S40)		IT (13S40)	115 d (10C51a); 90 d (13S40)		0.0885 (K/L 0.75) spect conv (67H49, 67H49a); 0.0887 spect conv (10C51a); 0.086 (e/γ very large, K/L 0.75) spect conv (2H41)	 Te^{127m} (11/2−) 0.089 Te^{127} (3/2+) 0 β$^-$ (5/2+) (18G52)	Te-n-γ (13S40, 2S47); Te-d-p (13S40); Te^{126}-n-γ (67H49); I-n-p (13S40); fission U (38G46, 33G51i, 43W48), U^{233} (61S48, 38G48, 38G51), U^{235} (38G51); parent Te^{127} (13S40, 33G51i, 43W51); daughter (16%) Sb^{127} (78B48)
Te^{127}	A chem (28T38, 32A39); chem, excit, cross bomb (13S40)		β$^-$ (32A39)	9.3 h (13S40)	0.7 abs (33G51i)	no γ (33G51i)		Te-n-γ (13S40, 2S47); Te-d-p (28T38, 13S40); Te-n-2n (28T38); I-n-p (13S40); fission U (32A39, 13S40, 43W48, 33G51i), U^{233}, U^{235} (38G51); daughter Te^{127m} (13S40, 33G51i, 43W51); daughter Sb^{127} (32A39, 33G51i), (84%) (78B48)
Te^{128}		31.79 (1B50)					Te^{128}, I = 0 (87M50)	
Te^{129m}	A chem, genet (13S40)		IT (13S40)	33.5 d (10C51a); 32 d (13S40, 1N51a)		0.1060 spect conv (10C51a); 0.106 (K/L ~1) spect conv (67H49); 0.102 (e/γ very large, K/L ~1) spect conv (2H41)	 Te^{129m} (11/2−) 0.106 Te^{129} (3/2+) 0 β$^-$ I^{129} (7/2+) 0 (18G52, HPS)	Te^{128}-n-γ (67H49); Te-n-γ (13S40, 2S47); Te-d-p (13S40); Te-n-2n (28T38); Te-γ-n (25W48); fission U (16H43b, 38G46, 43W48, 1N51a, 30P51a), U^{233} (38G48, 38G51), U^{235} (38G51); parent Te^{129} (13S40, 38G46, 43W51)
Te^{129}	A chem, excit (37B39, 13S40)		β$^-$ (13S40)	72 m (13S40); 70 m (32A39, 33G51i); 67 m (25W48)	1.8 spect (11R47); 1.7 abs (33G51i)	0.3, 0.8 abs (33G51i)		Te-n-γ (13S40, 2S47); Te-d-p (13S40, 28T38); Te-γ-n (37B39, 25W48); Te-n-2n (6H37, 28T38); fission Th (72B51), U (32A39, 16H43b, 38G46, 43W48, 1N51a); daughter Te^{129m} (13S40, 38G46, 43W51); daughter Sb^{129} (32A39)
Te^{130}		34.49 (1B50)		double beta decay; ~10^{21} y Xe ratios, mass spect (3I50b)			Te^{130}, I = 0 (87M50)	
Te^{131m}	A chem, genet (13S40)		IT (13S40)	30 h (32A39, 13S40)		0.177 (K/L 2) spect conv (2H41)	 Te^{131m} (11/2−) 0.177 Te^{131} (3/2+) 0 45% 55% β$^-$ 0.8 0.16 I^{131} (7/2+) 0 (18G52, 37G52)	Te-n-γ (13S40, 2S47); Te-d-p (13S40); spall-fission U (6F51); fission U (32A39, 16H39a, 32K51d, 43W51, 30P51a); parent Te^{131} (32A39, 13S40, 43W51); daughter Sb^{131} (68C51)
Te^{131}	A chem, excit (13S40)		β$^-$ (13S40)	24.8 m (37G52); 25 m (13S40)	2.0 (~55%), 1.4 (~45%) abs, β-γ coinc (37G52)	0.16, 0.7 abs (37G52)		Te-d-p (13S40); Te-n-γ (13S40, 2S47, 37G52); fission U (32A39); daughter Te^{131m} (32A39, 13S40, 43W51); parent I^{131} (32A39, 13S40, 30P51, 68C51); daughter Sb^{131} (30P51, 68C51)

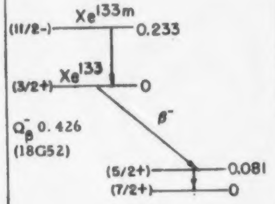
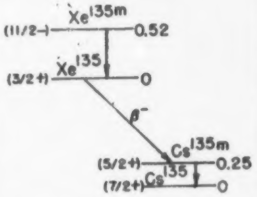
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{52}Te^{132}$	B chem (32A39); fission fragment range (32K48)		β^- (32A39)	77.7 h (30P51a); 77 h (32A39)	0.22 spect (10L51a); 0.3, ~0.1 (?) abs (1N51b); ~0.3 abs (70B43a)	0.231 scint spect (10L51a); 0.22 abs (1N51b)		Te-α-2p (112S51); spall-fission Th (7N49a); fission Th (16H39d, 72B51, 21T51), U (32A39, 16H39e, 16H39a, 1N51b, 30P51a), Pu (32K48); daughter Sb^{132} (32A39, 30P52a); parent I^{132} (32A39, 16H39e, 16H39a, 1N51b, 44W51)
Te^{133m}	A chem, genet (32A39)		IT (30P52)	63 m (30P52); 60 m (32A39, 16W40)		~0.4 scint spect (30P52); with Te^{133}: 0.6, 1.0 abs (30P52)	 Te^{133m} (11/2−) 0.4 Te^{133} (3/2+) 0 ~70% ~30% β^- 1.6 (5/2+)(?) 0.6 I^{133} (7/2+) 0 (30P52)	fission U (32A39, 16H39a, 24S40, 16W40, 30P51), Pu (32K48); parent Te^{133} (30P52); ancestor I^{133} (32A39, 16H39a, 24S40, 16W40, 16W45, 30P51); daughter Sb^{133} (30P51)
Te^{133}	A chem, genet (30P52)		β^- (30P52)	2 m (30P52)	2.4 (~30%), 1.3 (~70%) abs (30P52)	0.6, 1.0 abs (30P52)		daughter Te^{133m} (30P52); parent I^{133} (30P52a)
Te^{134}	B chem, genet (32A39)		β^- (32A39)	44 m (30P51a); 43 m (32A39)				fission Th (9P40), U (32A39, 16H39a, 30P51a), Pu (32K48); parent I^{134} (32A39, 16H39a, 30P51a)
Te^{135}	[A] genet (22D40)		β^- (22D40)	<2 m (33G51j, 32K51e, 22D40)				fission U, parent I^{135} (33G51j, 32K51e)
Te	E chem (16H43b)		β^- (16H43b)	~1 m (16H43b)				fission U (16H43b)
$_{53}I^{120}$	D chem (74M50)		β^+ (74M50)	30 m (74M50)	4.0 abs, spect (74M50)			spall Sn (second order reaction) (74M51); Sb-α-5n (74M50)
I^{121}	B chem, genet (74M50)		β^+ (74M50)	1.5 h (40D52); 1.8 h (74M50)	1.2 abs, spect (74M50); 1.2, 4.0 (weak) (40D52); conv: 0.185 spect (74M50)			spall Sn (second order reaction) (74M51); Sb-α-4n, parent Te^{121} (74M50); daughter Xe^{121} (37T52, 8H52b, 40D52)
I^{122}	A chem, excit (74M50); sep isotopes (7Y51)		β^+ (74M50)	3.6 m (7Y51); 3.4 m (40D52); 4 m (74M50)	2.9 abs (74M50); 3.1 abs (7Y51)			Sb-α-3n (74M50); Te^{122}-p-n (7Y51); daughter Xe^{122} (37T52, 8H52b, 40D52)
I^{123}	A chem, excit (74M50); chem, sep isotopes (14M49)		EC (74M50)	13.0 h (14M49); 13 h (74M50)		0.159 spect, spect conv (14M49)		spall Sn (second order reaction) (74M51); Sb-α-2n (74M50); Sb^{121}-α-2n (14M49); daughter Xe^{123} (37T52, 8H52b, 40D52)

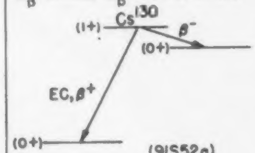
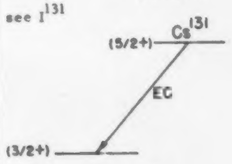
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{53}I^{124}$	A chem, excit, cross bomb (12L38e)		EC ~70%, β^+ ~30% (74M50)	4.5 d (74M50); 4.0 d (12L38e, 2D40)	2.20 (51%), 1.50 (44%), 0.7 (5%) spect (14M49); 2.1 spect, abs (74M50)	0.603, 0.73, 1.72, 1.95 spect, spect conv (14M49); no γ coinc with 2.2 β^+, β-γ coinc (85S51); γ-γ, β-γ coinc (37M49)	see Sb^{124}  I^{124} 5% 44% 51% β^+ 2.32 1.96 1.33 0.603 0 (14M49)	spall Sn (second order reaction) (74M51); Sb-α-n (12L38e, 74M50); Sb-α-3n (74M50); Sb^{121}-α-n (74M50); Te-p-n (2D40); spall-fission Bi (11G49, 66B51)
I^{125}	A chem (17R46a); chem, excit (33G47); genet (67B51b)		EC (L/K 0.23) (38M52); EC (L/K 0.3) (23F51b); no β^+ (33G47)	60.0 d (23F51b); 56 d (17R46a)		0.035 ion ch (23F51b); 0.0355, no 0.109 γ spect conv (67B51b)	see Te^{125m} Q_{EC} ~0.13 calc (38M52)  (23F51b)	Sb-α-2n (74M50); Te-d-n (17R46a, 33G47); spall-fission Bi (11G49, 66B51); daughter Xe^{125} (67B51b); not parent Te^{125m} (lim 0.05%) (23F51b)
I^{126}	A excit (28T38); chem, excit, cross bomb (12L38e)		EC ~58%, β^- ~40%, β^+(?) ~2% (12P51)	13.0 d (12L38e); 13 d (28T38)	β^-: 1.268 (27%), 0.85 (73%) spect (14M49); 1.24 (~25%), 0.85 (~75%) spect (12P51); 0.865 spect (23M51a)	with β^-: 0.382 spect conv, β-γ coinc (12P51); 0.395 spect, spect conv (14M49); with EC: 0.64 (weak) scint spect, x-γ coinc, γ-γ coinc (12P51); others (85S51)	Q_{β}^- 1.27 (12P51)  (12P51, 85S51a)	spall Sn (second order reaction) (74M51); Sb-α-n (12L38e, 74M50); Te-d-n (12L38e); Te-p-n (2D40); I-n-2n (12L38e, 28T38, 12P51); I-γ-n (12P49, 27M49, 3O50); spall-fission Bi (11G49, 66B51)
I^{127}		100 (6N37)					I^{127}, I = 5/2 (87M50)	
I^{128}	A chem, n-capt (12A35)		β^- 95.0%, EC + β^+ 5.0% (28R50); EC/β^- 0.063 (41M51a)	24.99 m (69H41)	2.02 spect (7S46)	0.428 (7%) spect (7S46)	Q_{β}^- 2.0 (7S46)  (7S46)	I-n-γ (12A35, 28T38, 2S47, 7S46, 9C49, 50H51); Te-d-2n (12L38e); Te-p-n (2D40)

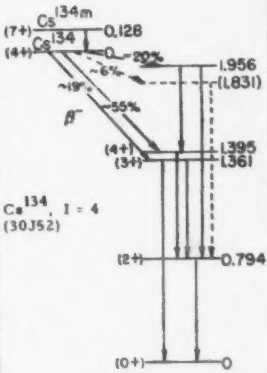
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{53}I^{129}$	A chem, n-capt (32K47)		β^- (32K47)	1.72×10^7 y sp act (32K51f); 3×10^7 y sp act (26P49b)	0.12 scint spect (38M52); 0.12 abs (26P49b), 0.12 ion ch (83B50); 0.13 abs (32K51f)	0.039 (coinc with β^-, e_K/γ ~6, K/L ~40) ion ch, β-γ coinc (83B50)	I^{129}, I = 7/2 (87M50)  I129 (7/2+) β⁻ Q_β^- ~0.17 (HPS) (3/2+) 0.039 (1/2+) 0 (83B50, 30T52, 18B52)	fission U (32K47, 26P49b, 83B50)
I^{130}	A chem, cross bomb (12L38e)		β^- (12L38e)	12.6 h (12L38e)	1.03 (~60%), 0.61 (~40%) spect (33R43)	0.744 (e_K/γ 0.003), 0.667 (e_K/γ 0.004), 0.537 (e_K/γ 0.007), 0.417 (coinc with 0.6 β^-, e_K/γ 0.012) ($e_K >> e_L$ for all γ's) spect, spect conv, β-γ, γ-γ coinc (33R43)	 (33R43)	Te-d-2n (12L38e); Te-p-n (2D40); I^{129}-n-γ (32K47); Cs-n-α (16W40)
I^{131}	A chem (12L38e); chem, genet (13S40)		β^- (12L38e)	8.141 d (39S51a); 8.05 d (106B52); 8.16 d (17K51); 8.04 d (38S51)	0.815 (0.7%), 0.608 (87.2%), 0.335 (9.3%), 0.250 (2.8%) spect, β-γ coinc (8B52); 0.810, 0.606, 0.335, 0.250 spect, β-γ coinc (24K51); 0.807, 0.606, 0.339 spect (40R52); E (average) 0.189 ion ch (77C52); see also: (69C52, 11B52, 8V51, 20N51, 10C51b, 30T51, 11B51, 22F50, 28K49, 44M48, 25D42)	0.080 (2.2%, coinc with 0.284 γ, e_K/γ 1.73, K/L 7), 0.163 (coinc with Xe^{131m_2}), 0.284 (5.3%, coinc with 0.608 β^-, e_K/γ 0.047, K/L 5), 0.364 (80%, coinc with 0.608 β^-, e_K/γ 0.018, K/L 8), 0.637 (9%, coinc with 0.335 β^-, e_K/γ 0.0037, K/L 9), 0.722 (3%, coinc with 0.250 β^-, e_K/γ 0.0028, K/L 8) spect, spect conv, β-γ delay coinc, scint spect (8B52, 8B52a); γ_1 0.080133, γ_2 0.28413, γ_3 0.36418 ($\gamma_1/\gamma_2/\gamma_3$ = 5/9/100) cryst spect (29L49a); γ_2 0.284 (e_K/γ 0.052, K/L 3.3), γ_3 0.364 (e_K/γ 0.021, K/L 5.6), γ_4 0.638 (e_K/γ 0.0040), γ_5 0.723 (e_K/γ 0.0034) ($\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 6/100/10/3) spect, spect conv (93H52a); 0.080 (4.3%, with 0.283 γ, e/γ 1.83) γ-γ, x-γ coinc, scint spect (69C52a); see also: (11B52, 48B52, 69C52, 86S52, 8V51, 30T51, 24K51, 10C51b, 22F50, 28K49, 48B49, 44M48, 13O48, 25D42, 40R52, 52W51, 24E51)	Q_β^- 0.972 (8B52)  I131 (7/2+) β⁻ 87.2% 2.8% 0.7% 9.3% (5/2,7/2+) 0.722 (5/2,7/2+) 0.637 (5/2+) 0.364 (11/2-) Xe131m2 0.163 (1/2+) Xe131m1 0.080 (3/2+) 0 (8B52, 48B52)	Te-d-n (12L38e, 33R41a); spall-fission Th (7N49a), U (16F41, 6O47, 6F51); fission Th (21T51), U (32A39, 16H39a, 38G46, 23S51j, 32K51), U^{233} (1Y47, 38G48, 61S48, 38G51), U^{235} (1Y47, 38G51), Pu (28F51); daughter Te^{131} (12L38e, [illegible]39, 16H39a, 13S40, 30P51, 68C51); parent (~1%) Xe^{131m_2} (48B49, 67B50b); parent Xe^{131m_1} (14G51a)
I^{132}	B chem, genet (32A39)		β^- (32A39)	2.4 h (32A39); 2.3 h (16H39a)	2.2, 0.9 abs (1N51b); 1.5 abs (75S49); ~1.4 abs (70B43a)	γ_1 0.69, γ_2 1.41, γ_3 2.0 ($\gamma_1/\gamma_2/\gamma_3$ = 37/4/1), γ_4 ~0.8 (very weak) scint spect, γ-γ coinc (46M51); 0.6, 1.4 abs (1N51b)		spall-fission U (16F41, 6O47); fission Th (72B51, 21T51), U (32A39, 16H39a, 9P40, 38G46, 1N51b), U^{233} (38G48); daughter Te^{132} (32A39, 16H39a, 16H39e, 1N51b, 44W51)

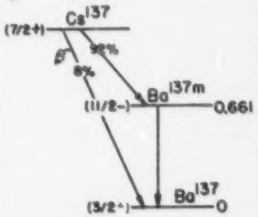
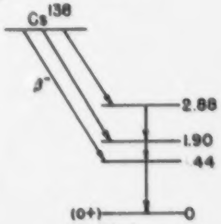
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{53}I^{133}$	A chem (32A39); chem, genet (16W40)		β^- (32A39, 16H39a)	20.5 h (106B52); 22.4 h (30P51a)	1.3 (~91%), 0.4 (~9%) abs (30P52a); 1.4 (~94%), 0.5 (~6%) abs, β-γ coinc (48B49a); 1.4 abs (23S51j)	0.53 (94%), 0.85 (5%), 1.4 (1%) scint spect, γ-γ coinc (48B49a); 0.53 spect (6P47b); 0.55 abs (23S51j)		spall-fission Pb (2T47b), U (16F41, 6O47); fission U (32A39, 16H39a, 24S40, 16W40, 30P51, 23S51k), Pu (28F51); daughter Te^{133} (32A39, 16H39a, 24S40, 16W40, 16W45, 30P51); parent Xe^{133} (24S40, 16W40, 16W45); parent (2.4%) Xe^{133m} (8Z51, 24K51a)
I^{134}	B chem (32A39); fission fragment range (32K48)		β^- (32A39)	52.5 m (30P51a); 51 m (32L49); 54 m (32A39)	1.6 (~70%), 2.8 (~30%), hard β (weak) abs (30P52a); 1.5-1.75, 3.5-4.2 abs (32L49)	>2.2 (weak) D-γ-n reaction (32L49); >1 abs (32K51h)		spall-fission U (16F41); fission Th (22D39), U^{235} (1Y47, 38G51), U (16H39a, 32A39, 9P40, 9P40a, 32L49, 32K51h, 30P51a), Pu (32K48, 28F51); daughter Te^{134} (16H39a, 32A39, 30P51a)
I^{135}	A chem, genet (22D40, 24S40)		β^- (22D40, 24S40)	6.68 h (6P47b); 6.7 h (33G51j, 32K51e)	0.5 (35%), 1.0 (40%), 1.4 (25%) spect (6P47b); 1.4 abs (32K51e); 1.5 abs (23S51j)	1.8, 1.27 spect (6P47b); 1.3 abs (23S51j); 1.6 abs (32K51e); 2.4 (1.1%) abs (32L49)		spall-fission U (6O47); fission Th (72B51), U (24S40, 16W40, 22D40, 16W45, 6P47b, 33G51j, 32K51e), Pu (28F51); daughter Te^{135} (33G51j, 32K51e); parent (~30%) Xe^{135m}, parent (~70%) Xe^{135} (6P47b); parent Xe^{135m} (40G40, 16W45); parent Xe^{135} (24S40, 22D40, 40G40, 16W45)
I^{136}	D chem (65S40)		β^- (65S40)	86 s (84S49)	6.5 abs (84S49)	1.4, 2.9 scint spect, abs (84S49, 99M52)		fission U (65S40, 66S43, 84S49), U^{233}, Pu (84S49)
I^{137}	A chem (65S40, 26S47); chem, genet (66S43, 63S49)		β^-, β^- n (~6% of disintegrations) (19L51a)	22.0 s (n) (28H48a); 22.5 s (n) (34R47); 19.3 s genet (63S49)	n (mean): 0.56 abs paraffin (28H48a); 0.67 p recoil in cl ch (71B46)			fission U (65S40, 66S43, 26S47, 34R47, 63S47a, 63S49), Pu (34R47); parent Xe^{137} (66S43, 63S49)
I^{138}	A chem, genet (63S49)		β^- (63S49)	5.9 s (63S49)				fission U, ancestor Cs^{138} (63S49)
I^{139}	A chem, genet (63S49)		β^- (63S49)	2.7 s (63S49)				fission U, parent Xe^{139}, ancestor Ba^{139} (63S49)
$_{54}Xe^{121}$	B chem, genet (37T52, 8H52b, 40D52)			40 m (40D52); 70 m (37T52); ~60 m (8H52b)				I-p-7n (37T52, 8H52b, 40D52); parent I^{121} (37T52, 8H52b, 40D52)
Xe^{122}	A chem, genet (37T52, 8H52b, 40D52)			19.5 h (37T52); 20.0 h (40D52); 19 h (8H52b)				I-p-6n (37T52, 8H52b, 40D52); parent I^{122} (37T52, 8H52b, 40D52)
Xe^{123}	A chem, genet (37T52, 8H52b, 40D52)		β^+ (40D52)	2.1 h (37T52); 1.7 h (40D52); ~2 h (8H52b)				I-p-5n (37T52, 8H52b, 40D52); parent I^{123} (37T52, 8H52b, 40D52)
Xe^{124}		0.096 (6N50a)						

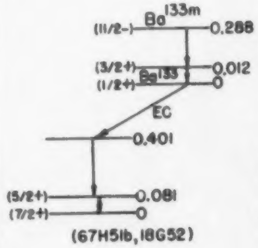
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{54}Xe^{125}$	A chem, sep isotopes (33A50); chem, mass spect (67B51b)		EC, no β^+ (67B51b, 33A50)	18 h (67B51b); 20 h (33A50)		0.054 (K/L ~4.3), 0.096, 0.106, 0.187 (K/L ~4.6), 0.243 spect conv; 0.460 scint spect (67B51b)		Te^{122}-α-n (33A50); Xe-n-γ (67B51b); parent I^{125} (67B51b)
Xe^{126}		0.090 (6N50a)						I-p-n (29C40b)
Xe^{127}	D chem (29C40b)		IT (?) (29C40b)	75 s (29C40b)		0.125, 0.175 spect conv (29C40b)		
Xe^{127}	A chem (29C40b); chem, sep isotopes (33A50); mass spect (67B51c)		EC (67B51c)	34 d (29C40b); 32 d (33A50); 25 d (67B51d)		0.057, 0.145, 0.170, 0.200, 0.365 spect conv, scint spect (67B51c)		Te^{124}-α-n (33A50); I-p-n (29C40b); I-d-2n (11O42); Xe-n-γ (44C44, 67B51c); daughter Cs^{127} (33F50)
Xe^{128}		1.919 (6N50a)						
Xe^{129m}	A chem, mass spect (67B51c)		IT (67B51c)	8.0 d (67B51c)		0.196 (K/L+M 2.1) spect conv (67B51c); 0.040 (K/L+M 4.3) spect conv (30T52, 30T52c)	 (11/2-) Xe129m 0.236 (7/2+) I129 β⁻ (3/2+) 0.040 (1/2+) 0 (30T52, 18G52)	Xe-n-γ (67P51c)
Xe^{129}		26.44 (6N50a)					Xe^{129}, I = 1/2 (87M50)	
Xe^{130}		4.08 (6N50a)						
Xe^{131m_2}	A chem (44C44); chem, genet (48B49); mass spect (67B50b)		IT (48B49, 44C44)	12.0 d (67B50b)		0.163 (K/L+M 1.9, L/M 3.4) spect conv (67B50b, 67B51c); 0.163 (K/L+M 1.7) spect conv (8V51); 0.165 (e/γ ~20) abs conv, abs (48B49)	see I^{131}  I131 β⁻ 0.7% (11/2-) Xe131m2 0.163 (1/2+) Xe131m1 0.080 (3/2+) 0 (48B52, 8B52, HPS)	Xe-n-n (44C44); daughter (~1%) I^{131} (48B49, 67B50b); not daughter Cs^{131} (43C51c); daughter Cs^{131} (70C50)
Xe^{131m_1}	A genet (14G51a)		IT (14G51a)	4.8×10^{-10} s delay coinc (14G51a, 8B52a)		0.080 scint spect (14G51a, 8B52a)		daughter I^{131} (14G51a, 8B52a)
Xe^{131}		21.18 (6N50a)					Xe^{131}, I = 3/2 (87M50)	fission U (mass spect) (13T47)
Xe^{132}		26.89 (6N50a)					Xe^{132}, I = 0 (87M50)	fission U (mass spect) (13T47)

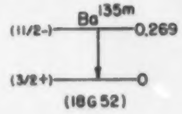
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{54}Xe^{133m}$	A chem (24K50c); mass spect (67B51a)		IT (24K50c)	2.3 d (67B51a); 2.1 d (24K51a)		0.233 (K/L 2.9) spect conv (67B51a); 0.235 (e_K/γ 4.2) spect conv, scint spect (24K51a)	 Xe133m (11/2-) 0.233 Xe133 (3/2+) 0 β- (5/2+) 0.081 (7/2+) 0 Q_β^- 0.426 (18G52) (18G52)	Xe-n-γ (67B51a); fission U (24K50c, 67B50c); daughter (2.4%) I^{133} (8Z51, 24K51a)
Xe^{133}	A chem (20L39, 22D40, 24S40); chem, excit (16W40); mass spect (13T47, 30T49)		β^- (22D40)	5.270 d (76M50); 5.3 d (18E51)	0.345 spect (67B50c); 0.34 abs (18E51), 0.35 abs (13E51e)	with Cs^{133m}: 0.081 (K/L 5.9) spect conv (67B50c); 0.08 γ (e_K/γ 1.8, K/L+M 6.0) scint spect, β-γ delay coinc (14G53); ~0.085 abs (13E51e); 0.08 cl ch (84B51)		Te-α-n (52C41); Xe-d-p (52C41); Xe-n-γ (21R43, 44C44); Xe-n-2n (21R43); Cs-n-p (16W40, 44C44, 16W45); Ba-n-α (16W40, 66S43b, 44C44, 16W45); fission U (24S40, 22D40, 16W40, 70B43a, 16W45, 13T47. 18E51, 84B51, 13E51e); daughter I^{133} (24S40, 16W40, 16W45); parent Cs^{133} (8Z51); parent Cs^{133m} (14G53)
Xe^{134}		10.44 (6N50a)					Xe^{134}, I = 0 (87M50)	fission U (mass spect) (13T47)
Xe^{135m}	A chem, genet (40G40, 16W45)		IT (16W45)	15.6 m (21R43); 15.3 m (6P47b); 13 m (1N51c)		0.52 spect (6P47b); 0.5 (e/γ ~0.2) abs, abs conv (16W45, 1N51c)	 Xe135m (11/2-) 0.52 Xe135 (3/2+) 0 β- Cs135m (5/2+) 0.25 Cs135 (7/2+) 0	Xe-n-2n (21R43); Xe-n-γ (21R43, 21R46); Ba-n-α (66S43b); fission U (40G40, 16W45, 13T47); daughter I^{135} (40G40, 16W45); daughter (~30%) I^{135} (6P47b); parent Xe^{135} (16W45)
Xe^{135}	A chem (24S40, 22D40); chem, excit (16W40); mass spect (30T49)		β^- (24S40)	9.13 h (60B52); 9.2 h (7N51, 58H51c); 9.1 h (30T49)	0.905 spect (67B51); 0.93 spect (6P47b); 0.95 abs (70B43a); 0.9 abs (16W45); 1.0 abs (7N51, 58H51c)	with Cs^{135m}: 0.250 (e_K/γ 0.05) spect conv, β^--conv coinc (67B51, 67B51d); 0.248 (K/L 7.0) spect conv, scint spect, β-γ delay coinc (14G53); 0.25 spect (6P47b)	(18G52, 14G53) Q_β^- 1.15 (67B51)	Xe-n-γ, Xe-n-2n (21R43); Xe-d-p (52C41); Ba-n-α (16W40, 66S43b, 16W45); fission U (24S40, 22D40, 84B51); daughter I^{135} (24S40, 22D40, 40G40, 16W45); daughter (~70%) I^{135} (6P47b); daughter Xe^{135m} (16W45); parent Cs^{135} (63S49a); parent Cs^{135m} (14G53)
Xe^{136}		8.87 (6N50a)					Xe^{136}, I = 0 (87M50)	fission U (mass spect) (13T47); daughter I^{137} (~6% of dis) (19L51a)
Xe^{137}	A chem (66S43); mass spect (30T49)		β^- (66S43)	3.9 m (63S49); 3.8 m (66S43); 3.4 m (21R43)	~4 abs (66S43, 70B43a)			Xe-n-γ (21R43, 66S43b, 63S49); fission U (66S43, 63S49, 33G51k); daughter I^{137} (66S43, 63S49); parent Cs^{137} (21T51b, 33G51k)
Xe^{138}	A chem (16H39a); mass spect (30T49)		β^- (16H39a)	17 m (36G40)				fission U (16H39a, 16H40a, 36G40, 66S43b); parent Cs^{138} (16H39a, 36G40, 66S43b)

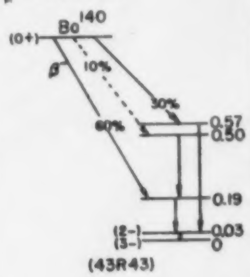
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{54}Xe^{139}$	A chem, genet (16H39a, 6H39)		β^- (16H39a, 6H39)	41 s (24D51)				fission Th (25A39, 16H40); fission U, parent Cs^{139} (16H39a, 6H39, 16H40a); ancestor Ba^{139} (16H39a, 6H39, 24D51); daughter I^{139} (63S49)
Xe^{140}	A chem, genet (16H40a)		β^- (16H40a)	16.0 s (24D51); 9.8 s (11O51)				fission Th (16H40); fission U, ancestor Ba^{140} (16H40a, 24D51a, 24D51, 11O51)
Xe^{141}	A chem, genet (17B51)		β^- (17B51)	1.7 s (32K46, 11O51); 3 s (24D51)				fission U, ancestor La^{141} (17B51); fission U, ancestor Ce^{141} (24D51a, 24D51, 11O51)
Xe^{143}	A chem, genet (17B51)		β^- (17B51)	1.0 s (24D51)				fission U, ancestor Ce^{143} (17B51, 24D51);
Xe^{144}	A chem, genet (24D51a)		β^- (24D51a)	~1 s (24D51)				fission U, ancestor Ce^{144} (24D51a, 24D51)
$_{55}Cs^{125}$	A chem, mass spect (73M52)		β^+ (73M52)	45 m (73M52)	2.03 spect (73M52)			I-α-6n (73M52)
Cs^{127}	A chem, mass spect (33F50)		β^+ (33F50)	5.5 h (33F50)	1.2 spect, abs (33F50)			I-α-4n (33F50); parent Xe^{127} (33F50); daughter Ba^{127} (37L52)
Cs^{128}	B chem, genet (33F51)		β^+, EC (37L52)	3.8 m (37L52); 3.1 m (33F51)	3.0 abs (33F50a, 32T50, 37L52)			daughter Ba^{128} (33F51, 37L52)
Cs^{129}	A chem, mass spect (33F50)		EC, no β^+ (33F50)	31 h (33F50)	conv: ~0.3 abs (33F50)	~0.5 abs (33F50)		I-α-2n (33F50); daughter Ba^{129} (33F50a, 32T50)
Cs^{130}	A chem (27R48); chem, excit (91S52a); chem, mass spect (73M52)		β^+, EC, β^- (β^+/β^- 27.5) (91S52a)	30 m (91S52a); ~30 m (27R48, 33F50)	β^+: 1.97 spect (91S52a); β^-: 0.442 spect (91S52a)	no γ (91S52a); Xe K-x (91S52a)	Q_β^- 0.442, Q_β^+ 2.99 (91S52a)  (91S52a)	I-α-n (27R48, 33F50, 91S52a)
Cs^{131}	A chem, genet (32K47a); chem, mass spect (7K49)		EC, no β^+ (28F47, 43C51c, 38K51d)	9.6 d (1Y49); 10.2 d (32K47a); 10.0 d (5Y47)		no γ (43C51c, 32K47a, 38K51d, 113S52); Xe K-x (43C51c, 5Y47, 1Y49, 32K47a, 28F47); ~0.1 abs conv, abs (5Y47, 1Y49)	see I^{131}  (18G52)	I-α-γ (112S51); daughter Ba^{131} (32K47a, 5Y47, 1Y49, 43C51c); not parent Xe^{131m_2} (43C51c); parent (?) Xe^{131m_2} (70C50)
Cs^{132}	B chem, excit (44C44)		EC (44C44)	7.1 d (44C44)		0.668 scint spect (10L51a); 0.62 abs, abs conv (44C44)		Cs-n-2n (44C44, 10L51a)

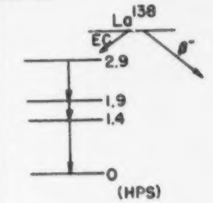
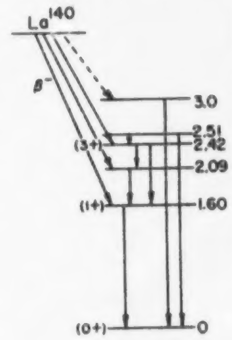
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{55}Cs^{133m}$	A genet (14G53)		IT (14G53)	6.0×10^{-9} s delay coinc (14G53)		see Xe^{133}; ~0.081 (e_K/γ 1.8, K/L+M 6.0) scint spect, β-γ delay coinc (14G53)		daughter Xe^{133} (14G53)
Cs^{133}		100 (6N37)					Cs^{133}, I = 7/2 (87M50)	
Cs^{134m}	A chem, n-capt (12A35, 77M35); chem, excit, n-capt (45K40)		IT (6P47, 18G48a, 42C50)	3.2 h (5S45); 3 h (45K40)		0.128 (K/L/M = 64.3/100/18.6) spect conv (42C50); 0.128 (e_K/γ 2.2) scint spect (14S51); 0.128 (L_{II}/L_{III} ~1) spect conv (63M52a); others (6P47, 18G48a, 5S45)	 Cs^{134m} (7+) 0.128 Cs^{134} (4+) 0 ~20% ~6% ~19% ~55% β⁻ 1.956 (1.831) (4+) (3+) 1.395 1.361 (2+) 0.794 (0+) 0	Cs-n-γ (12A35, 77M35, 45K40, 2S47); Cs-d-p (45K40)
Cs^{134}	A n-capt (30A38); chem, n-capt, excit (45K40)		β⁻ (45K40); no EC (lim 4%) (31W50); no EC (lim 5%) (7S48); no β⁺ (lim 0.009%) (41M51)	2.3 y (33G51ℓ) 1.7 y (45K40)	0.648 (75%), 0.09 (25%) spect (20P51); 0.65 spect (31W50); 0.66 (~72%), 0.09 (~28%) spect (4E47); 0.676, 0.640, ~0.08 (~24%) spect (87S52); 0.60, 0.09 abs, β-γ coinc abs (37M49); others (7S47c, 45K40, 6P47, 37W47)	0.561 (e_K/γ 0.005), 0.567 (e_K/γ 0.007), 0.601 (e/γ 0.005, K/L 6.0), 0.794 (e/γ 0.002, K/L 6.0), 1.037 (weak, K/L 4.5), 1.164 (weak, K/L 6.2), 1.365 (weak, K/L 6.1) spect conv (87S52); 0.560 (e/γ 0.008), 0.602 (e/γ 0.0053), 0.799 (e/γ 0.0025), 1.037 (weak), 1.170 (weak), 1.363 (with 0.09 β⁻, e/γ 0.00062) spect conv, β-γ coinc (31W50); 0.040 crit abs (47R52); γ_1 0.570, γ_2 0.601, γ_3 0.793, γ_4 1.024, γ_5 1.11, γ_6 1.35 ($\gamma_1/\gamma_2/\gamma_3/\gamma_6$ = 0.35/0.94/1.0/0.017) spect (88S51); γ_1 0.57, γ_2 0.60, γ_3 0.79 ($\gamma_1/\gamma_2/\gamma_3$ = 0.26/1.0/1.0) spect (4E47); no 1.96 γ (lim 10^{-4}%) Be-γ-n reaction (23W50); others (7S48, 20P51, 6P47, 20D50, 8B49, 45W50, 17B50, 44M50a, 85S51, 85B50, 39R51, 61K52)	Cs^{134}, I = 4 (30J52) (87S52)	Cs-n-γ (30A38, 69S38, 45K40, 2S47); Cs-d-p (45K40); Ba-d-α (51H43)
Cs^{135m}	A genet (14G53)		IT (14G53)	2.8×10^{-10} s delay coinc (14G53)		0.248 (K/L 7.0) spect conv, scint spect, β-γ delay coinc (14G53)	see Xe^{135}	daughter Xe^{135} (14G53)
Cs^{135}	A chem, genet (63S49a); chem, mass spect (31I49a)		β⁻ (63S49a)	3.0×10^{6} y sp act (8Z49); 2.1×10^{6} y yield (63S49a)	0.21 abs (63S49a); ~0.19 abs (8Z49)	no γ (63S49a, 8Z49)	Cs^{135}, I = 7/2 (87M50)	daughter Xe^{135} (63S49a); fission U (8Z49, 38W52)
Cs^{136}	A chem (33G46, 33G51m); chem, excit (33G49)		β⁻ (33G51m)	13.7 d (33G49)	0.35 abs (33G49); 0.28 β-γ coinc abs (28F51b)	~0.9 abs (33G49); 1.2 β-γ coinc abs (28F51b); two γ's (33G49)		La-n-α (44C44, 33G49); spall-fission Th (7N49a), U (6F51); fission Th (21T51), U^{233} (38G48, 38G51), U^{235} (38G51, 33G51m), Pu (28F51b, 33G51m)

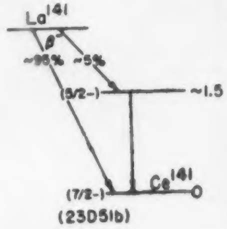
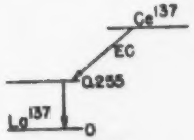
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{55}$Cs^{137}	A chem, genet (78M41); chem, mass spect (60H46a, 31l49a)		β^- (78M41)	33 y (33G5ln, 38W52)	β_1 0.523 spect (16A50); β_1 0.51 (92%), β_2 1.17 (8%) spect (10L51); β_1 0.521, β_2 ~1.2 spect (20P49); β_1 0.518, β_2 ~1.18 spect (15O49); others (31W51, 10L49, 31T48)	with Ba^{137m}, 0.6616 cryst spect (100M52); see Ba^{137m}; others (10L50d 79B52 31W51, 80H52, 40K52, 14M49a, 31T48, 20P49, 15O49)	Cs^{137}, I 7/2 87M50) Q_{β}^{-} 1.2 (HPS)  Cs137 (7/2+) β⁻ 92% 8% Ba137m (11/2-) 0.661 Ba137 (3/2+) 0 (31W51, 10L51)	spall-fission Th (7N49a); fission Th (21T51), U (60H48, 31l49a, 33G5ln, 38W52), U^{233} (38G48, 38G51), U^{235} (38G51), Pu (28F51); parent Ba^{137m} (13E48, 31T48); daughter Xe^{137} (21T5lb, 33G5lk)
Cs^{138}	A chem (16H39a, 6H39); chem, mass spect (30T49)		β^- (16H39a)	32.9 m (19E51); 33 m (25A39, 16H39a); 32 m (33G5lk, 36G40)	3.40 (coinc with 1.4 γ), ~2.9, ~2.0 spect, β-γ coinc abs (10L52a); 2.68 spect (30T49); 2.65 abs (35B46a, calc from 36G40)	γ_1 0.463, γ_2 0.98, γ_3 1.44 (coinc with γ_1 and γ_2) spect conv, scint spect, β-γ, γ-γ coinc (10L52a); 1.2 abs (33G5lk, 19E51)	see La^{138} Q_{β}^{-} 4.84 (10L52a)  (10L52a)	Ba-n-p (66S43b); fission Th (25A39, 16H40), Pa (2G39), U (6H39 16H40a); daughter Xe^{138} (16H40a, 36G40, 66S43b); descendent I^{138} (63S49)
Cs^{139}	A chem, genet (16H39a, 6H39)		β^- (16H39a)	9.5 m (63S50); 10 m (25A39, 6H39); 7 m (16H40a)				fission Th (25A39), U (16H39a 6H39 16H40a); daughter Xe^{139} (16H39a, 6H39, 16H40, 16H40a); descendent I^{139} (63S49); parent Ba^{139} (16H39a, 6H39, 16H40, 16H40a, 63S50)
Cs^{140}	A chem (16H40a); chem, genet (63S50)		β^- (16H40a)	66 s (63S50)				fission U (16H40a, 63S50); parent Ba^{140} (6 S50)
Cs^{141}	[A] genet (17B51)		[β^-] (17B51)	short (17B51, 24D51, 11O51)				[daughter Xe^{141}] 17 51 24D 1 O51); [ancestor La^{141}] (B51
Cs^{142}	D chem, genet (16H42a)		β^- (16H42a)	~1 m (16H42a)				fission U parent Ba^{142} (16H42a)
Cs^{143}	[A] genet (17B51)		[β^-] (17B51)	short (17B51, 24D51, 11O51)				[daught Xe^{143}] (17B51, 24D51 [ances o e ^{43}] 17B51, 24D51)
Cs^{144}	[A] genet (24D51a)		[β^-] (24D51a)	short (24D51a, 24D51)				[da e X ^{44}] (24D51); [an estor Ce^{144}] (24D51a, 24D5)

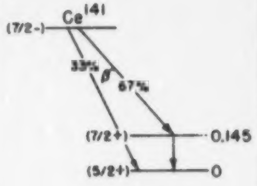
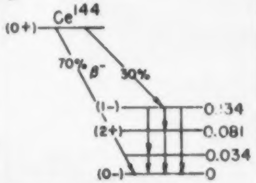
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{56}Ba^{127}$	A chem, genet (37L52)			~12 m (37L52)				Cs-d-8n, Cs-p-7n (37L52); parent Cs^{127} (37L52)
Ba^{128}	B chem (33F50a, 32T50)		EC (37L52)	2.4 d (33F50a, 32T50)				Cs-d-7n (37L52); Cs-p-6n (33F50a, 32T50, 37L52); parent Cs^{128} (33F51, 37L52)
Ba^{129}	A chem, genet (32T50, 33F50a)		β^+ (33F50a, 32T50)	2.0 h (33F50a); 1.8 h (32T50)	hard β^+ (32T50)			Cs-p-5n (33F50a, 32T50); parent Cs^{129} (33F50a, 32T50)
Ba^{130}		0.101 (6N38b)						
Ba^{131}	A chem, n-capt, excit (32K47a)		EC (32K47a); no β^+ (5Y47, 28F47)	12.0 d (32K47a); 11.7 d (5Y47)		γ_1 0.122 (K/L 6.0), γ_3 0.214 (K/L 2.8, e_K/γ ~0.18), γ_4 0.241, γ_5 0.370 (e_K/γ ~0.01), γ_6 0.494 (K/L 2.5, e_K/γ ~0.005), ~0.043 (?), ~0.065 (?), ~0.108 (?) ($\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 10/4/7/100) spect, spect conv (25E52); γ_1 0.122, γ_2 0.196, γ_3 0.213, γ_4 0.241, γ_5 0.371, γ_6 0.497 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 1.3/4.4/5.3/1.4/12/100) spect (43C51c); 0.122 (e/γ 0.8, K/L ~3.5), 0.206 (e/γ 0.15), 0.372 (e/γ 0.03), 0.494 (e/γ 0.01) spect, spect conv, γ-γ, conv-conv coinc (38K50a); ~0.5 (coinc with ~0.2 γ) γ-γ coinc abs (39C51); γ_7 1.2 abs (32K47a, 39C51); (γ_6/γ_7 ~4) (39C51); others (28D50a, 10Z50)		Ba-n-γ (32K47a, 5Y47, 1Y49, 28D50a, 10Z50, 43C51c); parent Cs^{131} (32K47a, 5Y47, 1Y49, 43C51c); spall-fission Bi (11G49)
Ba^{132}		0.097 (6N38b)						
Ba^{133m}	A chem, excit (10C41, 2D40)		IT (10C41)	38.8 h (46W43a); 38.9 h (5Y48)		0.276 (e_K/γ ~3) spect conv, scint spect (67H51a); 0.0117 (e/γ ~130) γ-γ coinc, ion ch (67H51b); 0.276 (K/L 3.2) spect conv (10C41)	 (11/2-) Ba^{133m} 0.288 (3/2+) Ba^{133} 0.012 (1/2+) 0 EC 0.401 (5/2+) 0.081 (7/2+) 0(67H51b, 18G52)	Cs-p-n (2D40); Cs-d-2n (10C41, 67H51a, 67H51b); Ba-γ-n (60M48); Ba-n-γ (5Y48); spall-fission Pt (13P47a), Bi (13P47, 11G49); parent Ba^{133} (5Y48)
Ba^{133}	A chem, n-capt, excit (32K47a); chem, genet (5Y48)		EC (32K47a)	~9.5 y (32K52a)		0.320 (e/γ 0.02), 0.085 (e/γ 0.3, K/L ~10) abs, abs conv, cl ch (5Y48); 0.36 abs, abs conv (32K47a)		Ba-n-γ (32K47a); daughter Ba^{133m} (5Y48)
Ba^{134}		2.42 (6N38b)					Ba^{134}, I = 0 (87M50)	

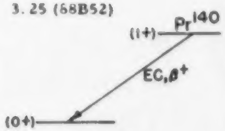
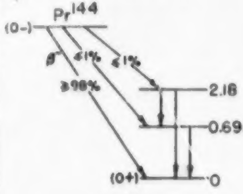
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{56}Ba^{135m}$	A chem (45K40); chem, n-capt, sep isotopes (67H5la)		IT (46W43, 5Y48)	28.7 h (5Y48)		0.269 (e_K/γ -3.5, K/L -2) spect conv, scint spect (67H5la); 0.267 spect conv, spect, scint spect (39C5la)	 (18G52)	Ba-n-γ, Ba-n-2n (45K40); Ba-d-p (46W43, 39C5la); Ba^{134}-n-γ (67H5la); spall-fission U (6O47)
Ba^{135}		6.59 (6N38b)					Ba^{135}, I = 3/2 (87M50)	
Ba^{136}		7.81 (6N38b)					Ba^{136}, I = 0 (87M50)	
Ba^{137m}	A n-capt (12A35); chem, genet (31T48, 13E48)		IT (31T48)	2.60 m (14M49a); 2.63 m (31T48); 2.5 m (13E48)		0.6616 cryst spect (100M52); γ_1 0.661 (K/L+M 4.64) spect conv (10L50d, 59G52); 0.661 (K/L/M+N = 5.5/1.0/0.27) spect conv (79B52); γ_1 (e_K/γ 0.097) spect, spect conv (31W51); γ_1 (e_K/γ 0.095) scint spect (80H52); 0.662 (K/L+M 4.57) spect conv (40K52); 0.663 (e_K/γ 0.13, K/L 4.8) spect conv (14M49a); γ_1 (e_K/γ 0.08, K/L 5.0) spect conv (15O49); 0.663 (e/γ 0.14) spect conv, x-conv coinc (31T48); 0.669 spect conv (20P49)	see Cs^{137}	Ba-n-2n (1P37, 45K40); Ba-n-γ (12A35); daughter Cs^{137} (13E48, 31T48)
Ba^{137}		11.32 (6N38b)					Ba^{137}, I = 3/2 (87M50)	
Ba^{138}		71.66 (6N38b)					Ba^{138}, I = 0 (87M50)	
Ba^{139}	A chem, n-capt (12A35); chem, excit (1P38a)		β^- (1P37a)	85.0 m (24D51c); 84 m (92S48); 86 m (1P37a, 16H40a)	2.27 spect (92S48); 2.3 abs (32K5li, 70B43a)	0.163 (26%, e/γ 0.20, K/L = 6), 1.05 (0.6%) spect conv, abs, coinc (92S48); -0.163 (e_K/γ 0.28) scint spect (52M52e)		Ba-d-p (1P37a, 45K40, 92S48); Ba-n-γ (12A35, 1P37, 2S47, 1Y49a); La-n-p (1P38a); Ce-n-α (46W43); spall-fission U (γ) (42L40), U (6F51); fission Th (25A39, 16H40, 72B51), U (6H39, 16H39a, 24D51), U^{235} (38G51), Pu (32K48, 28F51); daughter Cs^{139} (16H39a, 6H39, 16H40, 16H40a, 63S50); descendent Xe^{139} (16H39a, 6H39, 24D51)

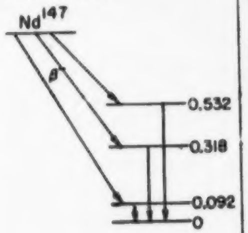
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{56}Ba^{140}$	A chem, genet (16H39, 16H39a)		β^- (16H39a)	12. 80 d (13E51f, 77S47)	1. 022 (60%), 0. 480 spect (86B49, 43R53); 1. 05 spect (4W51); 0. 99, 0. 47 spect (35L49); 1. 0 (~75%), ~0. 4 (~25%) abs (13E51g)	0. 0296, 0. 132, 0. 162, 0. 304, 0. 537 spect conv (10C51c); 0. 160, 0. 310, 0. 535 spect (35L49); 0. 03, 0. 16, 0. 31, 0. 54 spect, spect conv, scint spect, γ-γ coinc (86B49, 43R53); others (4W51, 26M49c)	Q_{β}^{-} 1. 05 (43R53)  Ba140 (0+) β- 10% 30% 60% 0.57 0.50 0.19 (2-) (3-) 0.03 0 (43R43)	Ba-n-γ (second order reaction) (32K51k); spall-fission Th (6O47, 7N49a), U (6C48, 6F51); fission Th (72B51, 21T51), U (16H39, 6H39, 16H40a, 36G40, 38G46, 63S50, 24D51, 24D51a, 17B51, 11O51, 4W51, 13E51f, 13E51g), U^{233} (61S48, 38G51), U^{235} (38G51), Pu (32K48, 28F51) descendent Xe^{140} (16H40a, 17B51, 24D51, 24D51a, 11O51); parent La^{140} (16H39, 16H39a, 16H40a, 36G40, 16H42a, 38G46, 28F51c)
Ba^{141}	A chem, genet (16H42a)		β^- (16H42a)	18 m (16H42a, 52G51)	2. 8 abs (32L48)	γ (52G51)		fission Th (16H39c, 16H39), U (16H42a, 52G51, 52G51a); photo-fission U (42L40); daughter Ce^{141} (16H42a); parent La^{141} (16H42a); descendent Xe^{141} (17B51, 11O51, 24D51)
Ba^{142}	D chem, genet (16H42a)		β^- (16H42a)	6 m (16H42a)				fission Th (16H39c, 16H39), U (16H42a); photo-fission U (42L40); daughter Ce^{142} (16H42a); parent La^{142} (16H42a)
Ba^{143}	B chem (16H39)		β^- (16H42a)	<0. 5 m (16H42a)				fission Th (16H39c), U (16H39c, 16H39, 16H42a, 24D51, 17B51, 11O51); [descendent Xe^{143}] (17B51, 24D51)
Ba^{144}	[A] genet (24D51)		β^- (24D51)	short (24D51, 24D51a)				[fission U, descendent Xe^{144}, ancestor Ce^{144}] (24D51, 24D51a)
$_{57}La^{131}$	A chem, mass spect (53G51)		β^+ (53G51)	58 m (53G51)	1. 6 abs (53G51)			spall Ba (53G51)
La^{132}	A chem, mass spect (53G51)		β^+ (53G51)	4. 5 h (53G51)	3. 5 abs (53G51)	1. 0 abs (53G51)		spall Ba (53G51)
La^{133}	A chem, mass spect (21N50)		EC, β^+ (weak) (21N50)	4. 0 h (21N50)	~1. 2 abs, spect (21N50); conv: 0. 26 spect conv (21N50)	0. 8 abs (21N50)		Cs-α-4n (21N50); daughter Ce^{133} (93S51)
La^{134}	B chem, genet (93S51)		β^+ ~44%, EC ~56% (93S51)	6. 5 m (93S51)	2. 7 abs, spect (93S51)	no γ (93S51)		daughter Ce^{134} (93S51)
La^{135}	A chem (81M42); chem, excit (73C48); chem, mass spect (21N50)		EC (81M42, 73C48)	19 h (21N50); 19. 5 h (73C48)		0. 76 (weak) abs (73C48); 0. 88 abs (46W43b)		Cs-α-2n (73C48, 21N50); Ba-d-n (81M42, 46W43b); Ba-p-n (46W43b); daughter Ce^{135} (73C48)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{57}La^{136}$	A chem (3M47); chem, excit, sep isotopes (36R50a)		EC ~67%, β^+ ~33% (21N50)	9.5 m (21N50); 9.0 m (36R50a); 10 m (3M47)	2.1 spect (21N50); abs (3M47); 1.8 abs (36R50a)			Ce-α-n (21N50, 36R50a); Ba-d-n (3M47); Ba^{135}-d-n, Ba^{136}-d-2n (36R50a)
La^{137}	C mass spect (3I48b)			>400 y yield (73C48); >30 y yield (3I48b)				[daughter Ce^{137}] (3I48b, 73C48)
La^{138}	A chem, mass spect (3I47a)	0.089 (3I47a)	EC (18P51); β^- ~6% (85M52a)	~2.0 x 10^{11} y sp act (18P51); ~7 x 10^{10} y sp act (85M52a)	1.0 abs (85M52a)	γ_1 1.39, γ_2 0.81, γ_3 0.54 ($\gamma_1/\gamma_2/\gamma_3$ = 1/0.65/0.3) scint spect (18P51); 1.0, 0.54 scint spect (11B50f)	see Ce^{138}  (HPS)	natural source (11B50f, 18P51)
La^{139}		99.911 (3I47a)					La^{139}, I = 7/2 (87M50)	
La^{140}	A n-capt (82M35); chem, excit, n-capt (1P38a); chem, mass spect (60H48)		β^- (1P38a)	40.0 h (72B51d, 9B50, 46W43b); 40.4 h (77S47); 39.5 h (37B46)	1.32 (~70%), 1.67 (~20%), 2.26 (~10%), others <1.3 (very weak) spect (86B49, 43R53); 0.90, 1.40, 2.12 spect (1O46); 1.45, 2.2 spect (4W51a); others (46W43b, 37B46)	γ_2 0.3286, γ_3 0.4867, γ_4 0.8151, γ_5 1.596 spect (12H52); γ_1 0.093, γ_2 0.335, γ_3 0.490, γ_4 0.820, γ_5 1.600, γ_6 2.50, γ_7 3.0 (weak) spect, spect conv, γ-γ coinc (86B49, 43R53); γ_1 0.093, γ_2 0.335, γ_3 0.49, γ_4 0.82, γ_5 1.62, γ_6 2.55 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = <1/3/22/16/56/3) scint spect (87B51); 0.069, 0.110, 0.131, 0.173, 0.241, 0.265, 0.329, 0.431, 0.486, 0.752, 0.816, 0.926, 1.597, 1.904 spect conv (10C51d); γ_2 0.335, γ_3 0.49, γ_4 0.87, γ_5 1.65, γ_6 2.3 ($\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 2/5/10/77/6) spect (11R47); γ_2 0.335, γ_3 0.49, γ_4 0.83, γ_5 1.63, γ_6 ~2.3 ($\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6$ = 1/10/20/100/5) spect (43M46); γ_5 (coinc with 2.3 β^- and γ_4) scint spect, β-γ, γ-γ coinc (39R51a); 2.55 (~4%), 2.9 (~0.1%) D-γ-p ion ch (9B50); 2.49 (~3%) D-γ-n, Be-γ-n reactions (42W47); others (26M48a)	Q_β^- 3.86 (39R51a, 43R53)  La^{140} β^- 3.0 2.51 2.42 (3+) 2.09 (1+) 1.60 (0+) 0 (43R53)	Ba-d-γ (?) (46W43b); La-d-p (1P37a, 1P38a, 81M42, 46W43b); La-n-γ (82M35, 1P38a, 40G42, 81M42, 46W43b, 2S47); Ce-n-p (46W43b); fission Th (72B51, 21T51), U (16H39, 16H39a, 16H40a, 36G40, 16H42a, 38G46, 28F51c), U^{233} (38G48, 38G51), U^{235} (38G47), Pu (28F51); spall-fission U (6F51) daughter Ba^{140} (16H39, 16H39a, 16H40a, 36G40, 38G46, 28F51c)

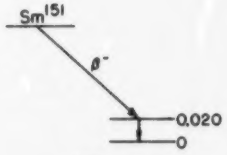
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{57}$La^{141}	A chem (16H42a); chem, genet (50B51, 23D51b)		β^- (16H42a)	3.7 h (32K51j); 3.5 h (16H42a)	2.43 (~95%), 0.9 (~5%) spect (23D51b)	1.3-1.6 (?, weak) scint spect, β-γ coinc (23D51b)	 La^{141} β^- ~95% ~5% (5/2-) ~1.5 Ce^{141} (7/2-) 0(23D51b)	La-n-γ (second order reaction) (32K49); fission Th (4C39, 72B51), U (16H42a, 32K51j); daughter Ba^{141} (16H42a); descendent Xe^{141} (17B51); parent Ce^{141} (50B51, 23D51b)
La^{142}	D chem (16H42a)		β^- (32K51j)	74 m (16H42a); 77 m (32K51j)		γ (32K51j)		fission Th (16H39c), U (16H42a, 32K51j); daughter Ba^{142} (16H42a)
La^{143}	A chem, genet (54G51)		β^- (54G51)	~19 m genet (54G51); ~15 m (16H43b)				fission U (16H42a, 16H43b, 54G51); parent Ce^{143} (54G51)
La^{144}	[A] genet (24D51a)		[β^-] (24D51a)	short (24D51a)				[descendent Xe^{144}, parent Ce^{144}] (24D51a)
$_{58}$Ce^{133}	A chem, genet (93S51)		EC, β^+ (93S51)	6.30 h (93S51)	1.3 spect, abs (93S51)	1.8 abs (93S51)		La-p-7n (93S51); parent La^{133} (93S51)
Ce^{134}	B chem, excit (93S51)		EC (93S51)	72.0 h (93S51)		K-x, no γ (93S51)		La-p-6n (93S51); spall Ta (22N52); parent La^{134} (93S51)
Ce^{135}	A chem, genet (73C48)		EC, $\beta^+ \leq 1\%$ (93S51)	22 h (93S51)	0.81 spect (93S51)			La-d-6n (73C48); La-p-5n (93S51); spall Ta (22N52); parent La^{135} (73C48)
Ce^{136}		0.193 (31I47a)						
Ce^{137}	A chem, excit (73C48); n-capt, sep isotopes (67H51c)		EC, no β^+ (73C48)	36 h (73C48)		0.257 (K/L ~4) spect conv (67H51c); 0.253 (K/L ~10) spect conv (11K51)	 (11K51, HPS)	La-d-4n (73C48); La-p-3n (93S51); Ce^{136}-n-γ (67H51c, 11K51); [parent La^{137}] (31I48b, 73C48)
Ce^{138}		0.250 (31I47a)						
Ce^{139}	A chem (1P43); chem, excit, cross bomb (1P48, 36M47); n-capt, sep isotopes (67H51c)		EC (36M47)	140 d (1P43, 1P48)		0.166 (K/L ~10), 0.275 spect conv (11K51); 0.166 (K/L ≥4) spect conv (67H51c); ~0.8 abs (1P48)		Ba-α-n (1P43, 1P48); La-d-2n (1P43, 36M47, 1P48); Ce^{138}-n-γ (67H51c, 11K51); Ce-n-γ (83M50); spall-fission Bi (11G49); daughter Pr^{139} (93S51)
Ce^{140}		88.48 (31I47a)						

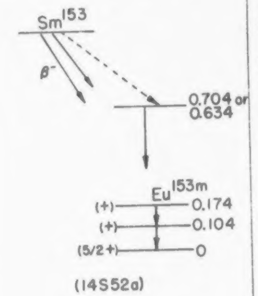
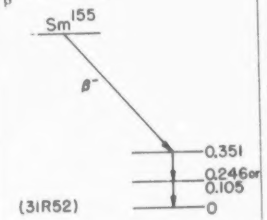
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{58}$Ce^{141}	A chem (16H40c); chem, excit, n-capt, cross bomb (1P43, 72B51e); chem, mass spect (60H48)		β^- (16H40c)	33.1 d (49W49); 32.5 d (3F50c); 30.6 d (1P48)	0.581 (33%), 0.442 (67%) spect (3F50c); 0.58 (29%), 0.44 (71%) spect (38K51c); 0.56 (30%), 0.41 (70%) spect (92S48a); 0.56 spect, β-γ coinc abs (11T49a); others (26M49e, 94S50, 1P48, 37B46)	0.145 (e_K/γ 0.25, K/L 5.5) spect conv, spect (3F50c); -0.14 (e_K/γ 0.46) scint spect (80H52a); 0.142 (e_K/γ 0.48) scint spect (17J52a); 0.145 (K/L -7) spect conv (67H51c); 0.144 (e/γ -0.33, K/L 6.5) spect conv (38K51, 38K51c); 0.146 spect conv (11K51, 11T49a); 0.141 (coinc with β^-) spect conv, β-conv coinc (92S48a); 0.14 (coinc with β^-) scint spect, β-γ coinc (23D51b); others (94S50, 26M49e, 4B49, 42H47a, 52M51)	Q_β^- 0.58 (3F50c)  Ce^{141} (7/2-) 33% β 67% (7/2+) 0.145 (5/2+) 0 (3F50c, 38K51c)	Ba-α-n (1P43, 1P48); Ce-d-p (1P43, 1P48, 72B51e, 50B51); Ce-n-γ (1P43, 10C48a, 72B51e); Ce-n-2n (1P43, 1P48, 72B51e); Pr-n-p (1P43); spall Ta (22N52); spall-fission Bi (11G49), U (6F51); fission Th (72B51, 21T51), U (16H40c, 50B51), U^{235} (38G51), Pu (28F51) daughter La^{141} (50B51, 23D51b); descendent Xe^{141} (11O51, 24D51)
Ce^{142}		11.07 (3I47a)						
Ce^{143}	A chem (63S46, 1P43); chem, cross bomb (1P48); chem, genet (72B51e); mass spect (5I48b)		β^- (63S46)	33 h (72B51e, 95S50, 37B46); 34 h (38K51c); 36 h (4B49, 1P43)	β_1 1.39, β_2 1.09, β_3 0.71 ($\beta_1/\beta_2/\beta_3$ = 1.0/1.3/1.0) spect (50B52); β_1 1.37, β_2 1.09, β_3 0.37 (?) (β_2/β_1 1.4) spect (38K51c)	0.035, 0.126, ~0.160, 0.289, 0.356, 0.660, 0.720 spect, spect conv, scint spect (50B52); γ_1 0.057 (K/L -1), γ_2 0.283 (K/L -6), γ_3 0.649, γ_4 0.705 ($\gamma_2/\gamma_3/\gamma_4$ = 4.5/1/1) spect, spect conv, β-γ coinc (38K51, 38K51c); 0.0575 (K/L <1), 0.291 (K/L -10), 0.348 spect conv (11K51); others (95S50)		Ce-d-p (1P43, 1P48, 72B51e); Ce-n-γ (1P43, 37B46, 1P48, 72B51e); Ce^{142}-n-γ (11K51); spall-fission Th (7N49a), U (6O48, 6F51); fission Th (72B51), U (17B51, 24D51, 63S51), Pu (32K48); daughter La^{143} (54G51); parent Pr^{143} (1P43, 37B46, 72B51e); descendent Xe^{143} (17B51, 24D51)
Ce^{144}	A chem (16H40c); chem, mass spect (60H48)		β^- (16H40c)	282 d (53S51); 275 d (50B51a); 290 d (19J44)	0.300 (70%), 0.170 (30%, coinc with 0.134 γ, with 0.080 γ) spect, β-γ coinc (34P52); 0.304 (70%) spect (19P52); 0.17 (coinc with 0.134 γ) β-γ coinc (24K52); others (70C52, 17N51b, 6P47, 26M50a)	0.0337, 0.054, 0.0807 (e/γ large, K/L -4), 0.100, 0.134 (K/L -9) spect conv, spect (19P52); 0.034, 0.041, 0.047, 0.054 (K/L <1), 0.081 (K/L -5), 0.095, 0.101, 0.135 (K/L -10) spect conv (11K51); 0.0547, 0.079 (K/L 6.3), 0.134 (K/L 8.3), 0.231 (K/L 1.7) spect conv (70C52); -0.132 (K/L 5.3) spect conv (40K52); 0.695, 1.50, 2.18 spect (15T50); others (13A52a, 2E51)	Q_β^- 0.304 (19P52)  Ce^{144} (0+) 70% β^- 30% (1-) 0.134 (2+) 0.081 0.034 (0-) 0 (19P52, 24K52, 34P52)	spall-fission Th (7N49a), U (6O48); fission Th (21T51), U (16H40c, 70B43a, 24D51, 7N51a, 50B51a), U^{233} (38G48, 61S48, 38G51), U^{235} (38G51), Pu (28F51); parent Pr^{144} (16H43b, 39G43, 7N51a); descendent Xe^{144} (24D51, 24D51a)
Ce^{145}	G not found: (78C52a)			-1.8 h (72B51f)				not found: fission U (78C52a); fission U (24D51, 72B51f); parent Pr^{145} (72B51f)
Ce^{146}	D chem, genet (40G43)		β^- (40G43)	14.6 m (53S45); 11 m (40G46)	-0.9 abs (78C52a)	soft γ (78C52a)		fission U, parent Pr^{146} (40G43, 16H43b, 53S45, 40G46)

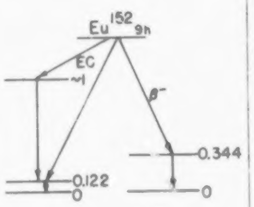
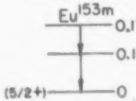
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{59}Pr^{137}$	B chem, mass spect (44D52)		β^+ (44D52)	1.4 h (44D52)	1.8 (44D52)			Ce-p-4n (44D52)
Pr^{138}	A chem, excit (93S51); chem, mass spect (44D52)		EC ~90%, β^+ ~10% (93S51)	2.0 h (93S51, 44D52)	1.4 abs, spect (93S51)	0.2, ~0.5, 1.3 abs (93S51)		Ce-p-3n (93S51, 44D52)
Pr^{139}	A chem, genet (93S51); chem, mass spect (44D52)		EC ~94%, β^+ ~6% (93S51)	4.2 h (44D52); 4.5 h (93S51)	1.0 abs spect (93S51)	1.0 abs (93S51)		Ce-p-2n (93S51, 44D52); parent Ce^{139} (93S51)
Pr^{140}	A excit (12A35); excit (1P38a)		β^+ 58%, EC 42% (88B52)	3.4 m (29D42); 3.5 m (1P38a)	2.23 spect (88B52)	no γ (88B52)	Q_β^+ 3.25 (88B52)  (88B52)	Ce-p-n (93S51); Pr-n-2n (12A35, 1P38a, 29D42); Pr-γ-n (34H45, 12P49); daughter Nd^{140} (2W49, 88B52)
Pr^{141}		100 (3I48c)					Pr^{141}, I = 5/2 (87M50)	
Pr^{142}	A n-capt (12A35, 82M35)		β^- (29D42); no β^+ or EC (lim 0.5%) (28R50b)	19.2 h (37B46); 19.1 h (13J50); 19.3 h (29D42)	2.15 (~96%), 0. [illegible] (13J50); 2.23, 0.66 spect (41R50); 2.14 spect (96M52, 29D42); 2.23 spect (6P47); 2.22, 0.22 abs, β-γ coinc abs (26M49d); 2.5, ~0.4 abs, β-γ coinc abs (15J49)	γ_1 0.135, γ_2 1.59 (γ_1/γ_2 <0.2) spect, spect conv (41R50); 1.58 spect (13J50, 13J52); 0.134, 0.329, 0.490, 0.624 spect conv; 2.1 abs (10C48); 1.5 coinc abs sec (15J49)	Q_β^- 2.23 (13J50, 26M49d)	La-α-n (29D42); Ce-p-n (29D42); Pr-d-p (29D42); Pr-n-γ (12A35, 82M35, 1P37, 1P38a, 29D42, 2S47); Nd-n-p (1P37, 1P38a); spall-fission U (6F51)
Pr^{143}	A chem (72B51g, 19J44); mass spect (60H46a)		β^- (72B51g, 19J44)	13.7 d (15F49a); 13.8 d (72B51h); 13.5 d (1P48)	0.932 spect (15F49a); 0.922 spect (49B50a); 0.920 spect (11T49a); 0.92 spect (38K51); 0.84 abs (26M49e)	no γ (72B51g, 72B51h, 1P48)	Q_β^- 0.93 (HPS)	Ce-d-n (1P48); spall-fission U (6F51); fission U (16H43b, 19J44, 72B51g), Pu (28F51) daughter Ce^{143} (1P43, 37B46, 72B51e)
Pr^{144}	A chem, genet (7N51a, 16H43b, 39G43)		β^- (7N51a)	17.5 m (7N51a, 77S51b); 17 m (16H43b)	2.97 (>99%), other β's (<1%) spect (19P52); 2.32 (<1%, coinc with 0.69 γ), 0.81 (<1%) spect, β-γ coinc (24K52); 2.95 (~95%), 0.87 (~5%) spect (10L52c); 2.97 (~90%), 2.3 (~5%), 0.86 (~5%) spect (13A52a); 2.99 spect (6P47); others (17N51b, 19J44, 50B51a, 70B43a, 16H43b, 26M50a, 70C52)	γ_1 0.0603, γ_2 0.696, γ_3 1.5, γ_4 2.19 (γ_2, γ_3, γ_4 weak) scint spect, spect, spect conv (19P52); γ_2 0.695, γ_3 1.48, γ_4 2.19 ($\gamma_2/\gamma_3/\gamma_4$ = 1/0.4/1.1) spect, β-γ, γ-γ coinc (13A52a); γ_1 0.061 (K/L <1) spect conv (11K51); others (17N51b, 77S51b)	Q_β^- 3.0 (13A52a, 19P52)  Pr^{144} (0-) β^- ≤1% ≤1% ≥98% 2.18 0.696 (0+) 0 (HPS)	fission Th (21T51), Pu (28F51); spall-fission U (6F51); daughter Ce^{144} (16H43b, 39G43, 7N51a)
Pr^{145}	G not found: (78C52a)			4.5 h (72B51f)				not found: fission U (78C52a); fission U (72B51f); daughter Ce^{145} (72B51f)
Pr^{146}	D chem (40G43)		β^- (40G43)	24.0 m (20K51a); 24.6 m (53S45a); 25 m (40G46)	3.8 abs (78C52a); ~3 abs (53S45a)	0.490, 0.78 scint spect (20K51a), 1.4 abs (53S45a)		fission U, daughter Ce^{146} (40G43, 16H43b, 53S45, 40G46)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{60}Nd^{138}$	D chem, excit (93S51)		β^+ (93S51)	22 m (93S51)	~2.4 abs (93S51)			Pr-p-4n (93S51)
Nd^{139}	A chem, genet (93S51)		EC ~90%, β^+ ~10% (93S51)	5.50 h (93S51)	3.1 abs, spect (93S51)	1.3 abs (93S51)		Pr-p-3n (93S51); ancestor Ce^{139} (93S51)
Nd^{140}	A chem, excit, genet (2W49)		EC (88B52)	3.3 d (2W49)		Pr K-x (88B52)		Pr-p-2n (93S51); Pr-d-3n (2W49); parent Pr^{140} (2W49, 88B52); spall-fission U (6F51)
Nd^{141}	A excit (47K42); chem, excit (2W49)		EC ~98%, β^+ ~2% (2W49)	2.42 h (2W49); 2.5 h (47K42)	0.7 abs (2W49); 0.8 abs (47K42)	1.2 (weak) abs (2W49)		Pr-p-n (47K42, 2W49); Pr-d-2n (2W49); Nd-n-2n (1P38a, 47K42); Nd-γ-n (47K42)
Nd^{142}		27.13 (3I48c)						
Nd^{143}		12.20 (3I48c)					Nd^{143}, I = 7/2 (97B50, 88M51)	fission U^{235} (mass spect) (3I50a)
Nd^{144}		23.87 (3I48c)						fission U^{235} (mass spect) (3I50a)
Nd^{145}		8.30 (3I48c)					Nd^{145}, I = 7/2 (97B50, 88M51)	fission U^{235} (mass spect) (3I50a)
Nd^{146}		17.18 (3I48c)						fission U^{235} (mass spect) (3I50a)
Nd^{147}	A chem, genet (84M47, 84M51a)		β^- (84M47, 84M51)	11.3 d (average of 31R52, 2E51a, 38K51a, 84M51, 37B46)	0.83 (~60%), 0.60 (~15%), 0.38 (~25%) spect (2E51a); 0.78 (~65%), 0.35 (~32%) spect (38K51a); 0.83, 0.60, 0.38 spect (31R52)	0.0918 (K/L_I = 6.4) spect conv (63M52); γ_1 0.0918 (e/γ ~0.9, K/L+M 6.5), γ_2 0.309, γ_3 0.391, γ_4 0.520 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 66/1/2/32) spect (38K51a); γ_1 (K/L/M = 7.55/1/0.096) spect conv (91S52d); 0.0912 (K/L 4.9), 0.121, 0.197, 0.231, 0.260, 0.273, 0.301, 0.318, 0.398, 0.441, 0.532 (K/L ~6) (all weak except 0.091 γ) spect conv, γ-γ, β-γ coinc (31R52); 0.0915 (coinc with 0.83 β^-), 0.320, 0.534 spect conv, β-conv coinc (2E51a); others (26M50b, 52M51)	Q_β^- 0.92 (31R52)  (31R52, 2E51a, HPS)	Nd-d-p (47K42); Nd-n-γ (37B46, 84M47, 10C48b, 84M51b); fission U (84M51); spall-fission U (6F51); parent Pm^{147} (84M47, 84M51a)
Nd^{148}		5.72 (3I48c)						U^{235}-n-fission (mass spect) (3I50a)
Nd^{149}	A excit (1P38a); chem, genet (84M51b)		β^- (1P38a)	2.0 h (37B46, 1P38a); 1.8 h (31R52); 1.7 h (84M51b)	1.5, 1.1, 0.95 spect (31R52); 1.5 abs (84M51b); 1.6 abs (37B46)	0.030, 0.097 (K/L 0.9), 0.112, 0.114 (K/L ~5), 0.124, 0.188, 0.198, 0.211 (K/L ~7), 0.226, 0.240, 0.266 (K/L ~10), 0.424, 0.538, 0.650 spect, spect conv, scint spect, coinc (31R52); others (52M51)	Q_β^- 1.5 (31R52)	Nd-n-2n (1P38a); Nd-d-p (1P38a); Nd-n-γ (1P38a, 37B46, 84M51b); parent Pm^{149} (42K52)
Nd^{150}		5.60 (3I48c)	β^- (?) (85M52, 3L34)	>2 × 10^{15} y sp act (85M52); >10^{13} y sp act (21C52)				fission U^{235} (mass spect) (3I50a)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{60}Nd^{151}$	B n-capt (84M51b); sep isotopes, n-capt, Pm K-L-M difference (31R52)		β^- (31R52)	15 m (51C52); 12 m (31R52, 84M51b)	1.93 spect (31R52)	0.085, 0.110, 0.117 (K/L 4), 0.421, 0.73, 1.14 spect conv, scint spect, β-γ, γ-γ coinc (31R52); Pm K-x (31R52)		Nd-n-γ (84M51b); Nd^{150}-n-γ, parent Pm^{151} (31R52)
$_{61}Pm^{141}$	B chem, excit (34F52)		β^+ (34F52)	20 m (34F52)	2.4-2.8 spect (34F52)			Nd^{142}-p-2n (34F52)
$Pm^{142,143}$	D chem, excit (2W50a)		EC (2W50a)	250-280 d (43L52a); 285 d (2W50a)		0.95 abs (2W50a)		Pr-α-2n (2W50a, 34F52); Nd-p-n (43L52a)
$Pm^{143,144}$	D chem (34F52)		EC (34F52)	200-400 d (34F52); 300-350 d (43L52a)		0.65, 0.44, 0.17 scint spect (34F52)		Pr-α-n, Pr-α-2n (34F52); $Nd^{143, 144}$-p-n (34F52); Nd-p-n (43L52a)
Pm^{145}	F sep isotopes (43L52a)		β^+ (43L52a)	14-18 d (43L52a)	0.45 (43L52a)			Nd-p-n (43L52a)
Pm^{145}	A chem, genet (65B51, 26P52)		EC (65B51)	~30 y yield (65B51)		Nd K, L-x (65B51, 26P52)		daughter Sm^{145} (65B51, 26P52)
Pm^{146}	B chem, excit (34F52)		β^- (?) (34F52)	~1 y (34F52); 1-2 y (43L52a)	0.7 abs (34F52); 0.75 (43L52a)			Nd^{146}-p-n (34F52); Nd-p-n (43L52a)
Pm^{147}	A chem (84M47, 84M51a); mass spect (60H48)		β^- (39G43, 72B51i)	2.6 y (53S51); 2.3 y yield (31I50a)	0.223 spect (10L50c); 0.227 spect (39W52a, 33L49); 0.229 spect (16A50)	no γ (84M47, 84M51a, 77S51c)	Q^-_β 0.223 (HPS)	fission U (39G43, 72B51i, 77S51c, 84M51a), U^{233} (38G48, 38G51), U^{235} (31I50a, 38G51); daughter Nd^{147} (84M47, 84M51a); parent Sm^{147} (42R50)
Pm^{148}	A chem, n-capt, mass spect (26P47)		β^- (47K43)	5.3 d (47K43, 26P47)	~2.5 abs (26P47); 2 abs (47K43)	~0.8 abs (26P47)		Nd-p-n (47K43); Nd^{148}-p-n (43L52, 34F52); Nd-d-2n (47K42, 47K43); Nd-α-p (47K42); Pm^{147}-n-γ (26P47); spall-fission U (6F51)
Pm^{148}	B excit, sep isotopes (43L52); chem (6F51)		β^- (43L52)	42 d (34F52); 43 d (6F51); 48 d (43L52)	2.4 (weak), 0.6 spect (6F51); 2.7 (weak), 0.7 abs (34F52); 1.7, 0.6 abs (43L52)	0.9 abs (6F51); 1.0 abs (34F52); 0.5 abs (43L52)		Nd^{148}-p-n (43L52, 34F52); spall-fission U (6F51)
Pm^{149}	A chem (84M47, 84M51c); chem, mass spect (31I47b)		β^- (84M47, 84M51c)	54 h (34F52); 55 h (31I47b); 50 h (31R52, 38K51c); 47.5 h (37B46); 47 h (84M51c, 16W42, 44L41)	1.05 spect (38K51a, 31R52, 34F52); others (26M49f, 37B46, 84M51c)	0.285 (coinc with β^-, K/L 8), ~1.3 (weak) spect conv, abs, β-γ coinc (31R52); no γ (38K51a); ~0.2 (coinc with β^-) β-γ coinc abs (26M49f); others (52M51)		Nd^{150}-p-2n (34F52); Nd-d-n, Sm-n-p, Sm-γ-p (44L41); fission U (84M47, 84M51c), Pu (32K48); spall-fission U (6F51); daughter Nd^{149} (42K52)
Pm^{150}	A excit, sep isotopes (43L52); chem, excit, sep isotopes (34F52)		β^- (43L52)	2.7 h (43L52, 34F52, 47K43)	2.01 (~70%), 3.00 (~30%) spect (34F52); 2.4 abs (43L52)	1.4, 0.3 abs (34F52)		Nd-p-n, Nd-d-2n (47K43); Nd^{150}-p-n (34F52, 43L52)

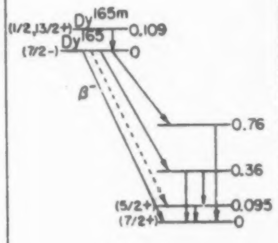
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{61}Pm^{151}$	B genet, Sm K-L-M differences (31R52)		β^- (31R52)	27.5 h (31R52)	1.1 abs (31R52)	0.065 (K/L 0.3), 0.066 (K/L 0.3) 0.070 (K/L 0.3), 0.100 (K/L ~5), 0.116, 0.144 (K/L ~9), 0.163 (K/L ~7), 0.168 (K/L ~3), 0.177 (K/L ~9), 0.208 (K/L ~4), 0.232, 0.240, 0.275 (K/L >10), 0.340 (K/L ~9), 0.715 spect conv, scint spect (31R52)		daughter Nd^{151} (31R52); fission U (51C52)
Pm	E (1P38a); chem (6F51)		β^- (1P38a)	12.5 h (6F51, 1P38a)				Nd-d- (1P38a); spall-fission U (6F51)
$_{62}Sm^{143}$	E chem (65B50)			8 m (65B50)				Sm-γ-n (65B50)
Sm^{144}		3.16 (3I48d)						
Sm^{145}	A mass spect (3I47c); chem (65B51); chem, sep isotopes, n-capt (26P52)		EC (65B51, 31R52)	~410 d (65B51); >150 d (10C48b); >72 d (3I47c)		0.061 (K/L 1.0) spect conv (31R52)		Sm^{144}-n-γ (26P52); Sm-n-γ (3I47c, 10C48b, 65B51); parent Pm^{145} (65B51, 26P52)
Sm^{147}	A chem (71H32); sep isotopes, mass spect (48W50); chem, genet, mass spect (42R50)	15.07 (3I48d)	α (71H32, 3L33)	$t_{1/2}$ corrected for abundance of Sm^{147} (HPS): 1.4×10^{11} y sp act (45L47); 1.5×10^{11} y sp act (72H35); 1×10^{11} y sp act (31P49)	2.18 ion ch (10J50); 2.14 range emuls (74C46); 2.1 range emuls (73H49); 2.0 cl ch (72H35); others (92B49)		Sm^{147}, I = 7/2 (105B52); Sm^{147}, I = 5/2 (88M51)	natural source (71H32, 3L33, 72B48, 1D48); daughter Pm^{147} (42R50): fission U^{235} (mass spect) (3I50a)
Sm^{148}		11.27 (3I48d)						
Sm^{149}		13.84 (3I48d)					Sm^{149}, I = 7/2 (105B52); Sm^{149}, I = 5/2 (88M51)	fission U^{235} (mass spect) (3I50a)
Sm^{150}		7.47 (3I48d)						
Sm^{151}	A mass spect (3I47c, 3I50a); chem (84M49)		β^- (3I47c)	73 y (7K52); ~120 y yield (3I50a)	0.076 spect (16A50, 39W52b); 0.079 spect (24K49e); 0.074 spect (84M49); no conv (31R52)	0.019 (coinc with β^-) ion ch, β-γ coinc (33W52); 0.021 ion ch (17S50); 0.021 scint spect (39W52b); no γ (84M49, 31R52); others (52M51)	 (33W52)	Sm-n-γ (3I47c); fission U (84M49); fission U^{235} (mass spect) (3I50a)
Sm^{152}		26.63 (3I48d)						fission U^{235} (mass spect) (3I50a)

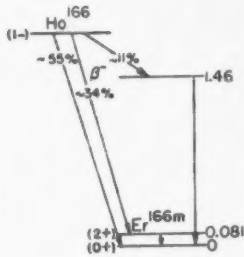
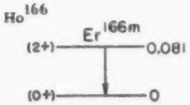
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{62}Sm^{153}$	A n-capt, excit (1P38a); mass spect (60H46, 3I47b); chem (51W51)		β^- (47K42)	47 h (51W51, 37B46, 47K42, 31R52)	0.80, 0.70 (coinc with 0.101 γ) scint spect, β-γ coinc (87B52); 0.68 (~67%), 0.80 (~33%) spect (11H50); 0.70 spect (7S51); 0.82 spect (31R52); 0.78 abs (82B48); 0.73 abs (51W51)	γ_1 0.070 (e_K/γ 3.1); γ_2 0.104 (e_K/γ 1.2, coinc with γ_3 or γ_4), γ_3 0.530, γ_4 ~0.60 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4$ = 100/425/1.0/0.3) scint spect, γ-γ coinc (14S52a); 0.069 (e_K/γ 3.8), 0.103 (e_K/γ 1.2, K/L+M 3.5) scint spect (52M52e); 0.070, 0.103 (coinc with 0.07 γ, e_K/γ 0.65, K/L ~6), 0.530 (weak) scint spect, spect conv, conv-conv coinc (7S51); 0.070 (weak, e/γ >10), 0.101 (e/γ ~3), no higher γ, scint spect, γ-γ coinc (87B52); 0.070 (K/L 3.5, $L_I/L_{II}/L_{III}$ = 26/1.3/1.3), 0.104 (K/L 6.5, $L_I/L_{II}+L_{III}$ = 43/2.3) spect conv (63M52a, 63M52b); 0.070 (coinc with 0.103 γ, K/L 0.29), 0.103 (K/L 3.5), 0.582 (weak) spect conv, γ-γ coinc (31R52); 0.069, 0.103 spect conv (67H48a); 0.102 (e/γ >2.5) spect conv, β-γ, β-conv coinc (11H50); others (43M46, 82B48)	 Sm153 β⁻ 0.704 or 0.634 Eu153m (+) 0.174 (+) 0.104 (5/2+) 0 (14S52a)	Nd-α-n (47K42); Sm-n-γ (71H36, 1P38a, 44L41, 16W42, 60H46, 2S47, 51W51); Sm-n-2n (1P38a, 47K42); Sm-d-p (44L41, 47K42); Sm-γ-n (44L41); spall-fission Th (7N49a), U (6F51); fission U^{233} (61S48), U^{235}, Pu (51W51); parent Eu^{153m} (52M50)
Sm^{154}		22.53 (3I48d)						fission U^{235} (mass spect) (3I50a)
Sm^{155}	B n-capt (12A35, 82M35); chem (51W51a)		β^- (47K42)	23.5 m (31R52); 25 m (51W51a); 21 m (1P38a)	1.8 (coinc with both γ's) abs, β-γ coinc (31R52); 1.9 abs (51W51a); 1.8 abs (47K42)	γ_1 1.05 (K/L 3.6), γ_2 0.246 (coinc with γ_1, K/L ~8) (γ_1/γ_2 ~1) spect, spect conv, γ-γ coinc (31R52)	Q_β^- 2.2 (31R52) 	Sm-n-γ (12A35, 82M35, 71H36, 1P38a, 44L41, 2S47, 3I47c, 51W51a); Sm-d-p (44L41, 47K42); fission U^{235} (51W51a), Pu (51W51a); parent Eu^{155} (3I47c)
Sm^{156}	A chem, genet (51W51b)		β^- (51W51b)	~10 h (51W51b)	0.9 abs (51W51b)			fission U (51W51b); spall-fission U (6F51); parent Eu^{156} (51W51b)
$_{63}Eu^{144}$	C excit, sep isotopes (74H52)		β^+ (74H52)	18 m (74H52)	2.4 spect (74H52)			Sm^{144}-p-n (74H52)
Eu^{145}	A chem, genet, sep isotopes, excit (74H51)		EC (74H51)	5 d (74H51)	conv: 0.2 abs (74H51)			Sm^{147}-p-3n (74H51); daughter Tb^{149} (74H51)
Eu^{146}	C excit, sep isotopes (74H51)		EC (74H51)	38 [illegible] (74H51)	conv: 0.4 abs (74H51)			Sm^{144}-α-pn, Sm^{147}-d-3n (74H51)
Eu^{147}	B chem, excit, sep isotopes (74H51)		EC 99+%, α ~10^{-3}%, no β^+ (74H51)	24 d (74H51)	α: 2.88 ion ch (74H51) conv: 0.2 abs (74H51)			Sm^{147}-p-n (74H51); Sm-d-2n, 3n (42R52)

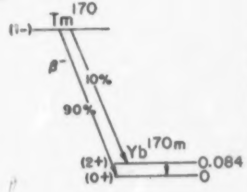
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{63}Eu^{148}$	A chem (84M51d); excit, sep isotopes (74H51, 86M52)		EC, no β^+ (74H51)	59 d (86M52); 54 d (2W50b); 50 d (74H51); 53 d (84M51d)	conv: 0.4 abs (74H51, 2W50b)	0.57 scint spect (74H52); 1.0, 0.4 abs (84M51d, 2W50b); 0.7 abs (86M52)		Sm^{148}-p-n (74H51, 86M52); Sm-p-n (2W50b); Sm-d-n (47K43, 84M51d)
Eu^{149}	E sep isotopes, excit (74H52)			~120 d (74H52)		~0.4 scint spect (74H52)		Sm^{149}-p-n (74H52)
Eu^{150}	A chem, excit (65B50); chem, excit, sep isotopes (74H52); excit, sep isotopes (86M52)		β^- (86M52)	15.0 h (2W50b); 15 h (65B50); 13.1 h (86M52)	1.8 spect (2W50b); 0.8, other β's (86M52)			Sm^{150}-p-n (74H52, 86M52); Sm-p-n (2W50b); Eu-γ-n (65B50)
Eu^{151}		47.77 (43H48)					Eu^{151}, I = 5/2 (87M50)	fission U (mass spect) (3I50a)
Eu^{152}	A n-capt, mass spect (3I47d); chem (84M49a)		EC, β^- (60H49)	13 y (7K52); 5.3 y yield (60H49)	1.58, others spect (11H50); 1.58, 0.75 spect (68S48); 1.7 (~20%), 0.9 (~80%) abs (84M49a)	0.122 (conv in Sm), 0.123 (conv in Gd), 0.244, 0.344, 0.720, 0.964, 1.086 spect conv (11K51, 10C50c); 0.121, 0.244, 0.344 spect conv (43K52); 0.121 (coinc with 0.244 γ), 0.123 (coinc with 0.344 γ), 0.244, 0.344 (not coinc with 0.244 γ) conv-conv coinc spect (35F50); others (11H50, 68S48)		Eu-n-γ (3I47d, 2S47)
Eu^{152}	A n-capt (82M35); n-capt, excit (1P38a); mass spect (60H46, 60H49)		β^-, EC (60H49)	9.2 h (1P38a, 60H49); 9.3 h (37B46)	1.880, 0.55 (?) (weak) spect (11H50); 1.88 spect (20T39)	γ_1 0.122 (conv in Sm, K/L ~4), γ_2 0.344 (conv in Gd, K/L ~10) spect conv (11K51); 0.122, 0.336 (coinc with β) pair spect, β-γ coinc (107S51); 0.120 (coinc with 0.9 or 0.8 γ), 0.94, 0.82 (not coinc with 0.9 γ) spect, spect conv, β-conv, γ-γ coinc (11H50); others (52W51, 20T39, 10C50c, 35F50, 23R39)	 (11K51, 11H50)	Eu-n-γ (82M35, 1P38a, 71H36, 5F41b, 2S47, 60H49); Eu-n-2n (1P38a); Eu-d-p (5F39, 5F41b)
Eu^{153m}	A genet (52M50)		IT (52M50)	3.0 x 10^{-9} s delay coinc (52M50)		0.069 (e_K/γ 3.8), 0.103 (e_K/γ 1.2, K/L+M 3.5) scint spect (52M52e)	 (18G52)	daughter Sm^{153} (52M50)
Eu^{153}		52.23 (43H48)					Eu^{153}, I = 5/2 (87M50)	fission U (mass spect) (3I50a)
Eu^{154}	A n-capt (69S38); mass spect (3I47d, 60H49); chem (84M49a)		β^- (60H49)	16 y (7K52); 5.4 y yield (60H49)	1.9 (~10%), 0.7 (~40%), 0.3 (~50%) abs (84M49a, calc from 60H49); ~0.7 (coinc with hard γ), 0.3 abs, β-γ coinc abs (84M49a); with Eu^{154} and Eu^{155}: 1.88, 0.90, 0.59, 0.25, 0.14 spect, β-γ coinc abs (24K50d); others (37B46, 26K48, 11H50, 37W47)	0.336, 0.778, 1.116 spect conv (11K51); with Eu^{154} and Eu^{155}: 0.085, 0.101, 0.725, 1.005, 1.288 spect (24K50d); 0.122 spect conv (43K52); others (26K48, 10C48b)		Eu-n-γ (69S38, 5F39, 5F41b, 2S47); Eu-d-p (5F41b, 26K48); Eu^{153} (fission product)-n-γ (84M49a); fission U (24K50d)

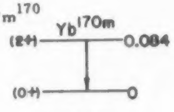
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{63}Eu^{155}$	A chem (51W51c); mass spect (60H49)		β^- (51W51c)	1.7 y (31R52); yield (60H49); 2.0 y (51W51c)	0.154 (80%), 0.243 (20%) spect, β-γ, γ-γ coinc (84M49a); see Eu^{154} β's (24K50d)	0.060 (weak), 0.087 (K/L ~8), 0.106 (K/L ~8) [illegible] (weak) spect conv (31R52); 0.085, 0.099 crit abs Pb, Pt (84M49a); 0.084 crit abs Tl, Hg (51W51c); 0.015 ion ch, β-γ coinc (33W52); see Eu^{154} γ's (24K50d)		Sm-d-n (47K43); Eu-n-γ (second order reaction) (60H49); spall-fission Th (7N49a); fission U (51W51c, 84M49a); daughter Sm^{155} (3I47c)
Eu^{156}	A chem (51W51b); mass spect (3I47b, 3I47c)		β^- (51W51b)	15.4 d (51W51b, 3I47c)	~0.5 (60%), 2.4 (40%) abs (51W5	2.0 abs (51W51b)		Eu-n-γ (second order reaction) (3I47c); spall-fission Th (7N49a), U (6O48, 6F51); fission U (51W51b), Pu (28F51); daughter Sm^{156} (51W51b)
Eu^{157}	D chem (51W51d)		β^- (51W51d)	15.4 h (51W51d)	~1.0 (~75%), ~1.7 (~25%) abs (51W51d)	0.6, 0.2 abs (51W51d)		spall-fission Th (7N49a); fission U (51W51d), Pu (32K48)
Eu^{158}	D chem (51W51d)		β^- (51W51d)	60 m (51W51d)	2.6 abs (51W51d)	γ (51W51d)		fission U (51W51d)
Eu^{159}	F excit (65B50)			20 m (65B50)				Gd-γ-p (?) (65B50)
$_{64}Gd^{148}$	B chem, excit, sep isotopes (42R52)		α, EC (?) (42R52)	>35 y (42R52)	α: 3.16 ion ch (42R52)			Sm-α-3n, Sm^{147}-α-3n (42R52); Eu-p-4n (42R52); spall Dy (42R52)
Gd^{149}	B chem, excit, sep isotopes, cross bomb (74H51)		EC 99+%, α ~10^{-3}% (42R52)	9 d (74H51)	α: 3.0 ion ch (74H51); conv: 0.35 abs (74H51)			Sm-α-2n, Sm^{147}-α-2n (74H51, 42R52); Eu-p-3n (74H51)
Gd^{150}	D chem (42R52)		α (42R52)	long (42R52)	α: 2.7 ion ch, range emuls (42R52)			Eu-d-3n (42R52)
Gd^{151}	F chem, excit (63H50)		EC, no β^+ (63H50)	150 d (63H50)		0.265 (e/γ large) abs (63H50)		Eu-d-2n (5F41b, 26K48, 63H50)
Gd^{152}		0.20 (1B50)						
Gd^{153}	A mass spect (3I47c); chem, n-capt (63H50)		EC, no β^+ (63H50)	236 d (63H50); 225 d (24K49a)		0.104 (K/L 5.2) spect conv (10C52c); 0.100 spect conv, abs (24K49a); 0.106 (e/γ >0.9) abs (63H50); others (10C48b)		Eu-d-2n (63H50); Gd-n-γ (3I47c, 10C48b, 24K49a, 63H50)
Gd^{154}		2.15 (1B50)						
Gd^{155}		14.73 (1B50)						
Gd^{156}		20.47 (1B50)						
Gd^{157}		15.68 (1B50)						
Gd^{158}		24.87 (1B50)						
Gd^{159}	B n-capt (2S47); chem (65B49, 63H50)		β^- (26K48)	18.0 h (65B49, 65B50, 26K48); 17.9 h (24K49b); ~24 h (63H50)	0.9 abs (26K48, 65B49)	0.055, 0.38 abs (65B49); ~0.3 abs (26K48); others (52M51)		Gd-n-γ (2S47, 24K49b, 65B49, 63H50); Gd-d-p (26K48); Gd-γ-n (65B50)
Gd^{160}		21.90 (1B50)						
Gd^{161}	C n-capt (3I46); n-capt, excit (65B49)		β^- (38M49)	3.6 m (65B49, 24K49b); 3.5 m (26K48); 3.3 m (38M49); 4.5 m (3I46)	1.5 abs (24K49c); ~2 (38M49)	0.37 abs (24K49c); ~0.07 (38M49)		Gd-n-γ (3I46, 26K48, 65B49, 38M49, 24K49b); parent Tb^{161} (24K49b, 24K49c)

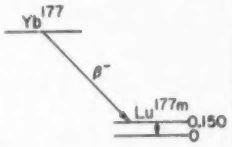
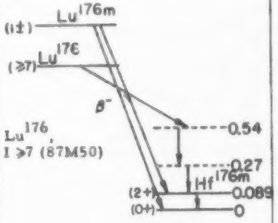
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{65}$Tb^{149}	A chem, mass spect (42R50)		α, EC (?) (42R52)	4.1 h (42R52)	α: 3.955 spect (42R52); 3.95 ion ch (42R52)			spall Gd, Dy (3T49, 42R52), Tb, Yb (42R52); parent Eu^{145} (74H51)
Tb^{151}	D chem, excit (42R52)		α, EC (?) (42R52)	19 h (42R52)	3.44 ion ch (42R52)			spall Eu (42R52), Gd, Tb, Dy (42R52)
Tb^{153}	B chem, excit (2W50c)		EC (2W50c)	5.1 d (2W50c)		1.2, 0.2 abs (2W50c)		Eu-α-2n (2W50c)
Tb^{154}	B chem, excit (2W50c)		EC 99+%, β^{+} ~0.5% (2W50c)	17.2 h (2W50c)	2.6 spect (2W50c)	1.3 abs (2W50c)		Eu-α-n, Eu-α-3n (2W50c); Gd-p-n (2W50c)
Tb^{155}	D chem, excit (2W50c)		EC (2W50c)	190 d (2W50c)		1.4 abs (2W50c)		Eu-α-2n (2W50c)
Tb^{156}	B chem, excit (2W50c)		EC >75%, β^{+} <25% (2W50c)	5.0 h (2W50c)	~1.3 abs (2W50c)			Eu-α-n (2W50c); Gd-p-n (2W50c)
Tb^{157}	B chem, excit, cross bomb (2W50c)		EC (2W50c)	4.7 d (2W50c)		1.4 abs (2W50c)		Gd-p-n (2W50c)
Tb^{159}		100 (43H48)					Tb^{159}, I = 3/2 (87M50)	
Tb^{160}	A n-capt (37B43); mass spect (31[illegible]7c); chem (6F51)		β^{-} (37B43); no β^{+} (82B50)	73.5 d (37P46); 71 d (82B50); 76 d (10C50d)	0.860 (43%), 0.521 (41%), 0.396 (16%) spect (82B50); ~0.90 β^{-} (coinc with 0.085 γ) scint spect, β-γ coinc (52M52)	0.962, 0.876, 0.410, 0.391, 0.375, 0.298, 0.282, 0.215, 0.196, 0.176, 0.093, 0.087 spect, spect conv (10C50d); 0.970, 0.886, 0.300, 0.200, 0.085 spect conv (82B50); with Dy^{160m}: 0.085 (e_K/γ 1.7) scint spect (52M52a); others (10C48b)		Gd-d-2n (26K48); Tb-n-γ (37B43, 37B46, 2S47); spall-fission U (6F51); parent Dy^{160m} (52M52, 52M52a)
Tb^{161}	B excit (26K48); chem, excit (24K49c)		β^{-} (26K48)	6.75 d (65B49); 6.8 d (10C52c); 7.2 d (63H50); 7 d (24K49a)	0.5 abs (63H50, 65B49, 24K49a)	0.049 (L/M 3.7) spect conv (10C52c); 0.026 ion ch (17S50); 0.05 abs (65B49, 24K49a)		Gd-d-[illegible] (26K48, 65B49); spall-fission U (6F51); daughter Gd^{161} (24K49b, 24K49c)
Tb^{162,163}	E excit (65B50)			14 m (65B50)				Dy-γ-p (?) (65B50)
$_{66}$Dy$^{<153}$	E cross bomb (42R52)		α (42R52)	7 m (42R52)	4.21 ion ch (42R52)			Nd-C-spall, Tb-p (42R52)
Dy$^{<153}$	E cross bomb (42R52)		α (42R52)	19 m (42R52)	4.06 ion ch (42R52)			spall Tb, Dy (42R52)
Dy$^{<153}$	D chem (42R52)		α (42R52)	2.3 h (42R52)	3.61 ion ch (42R52)			Nd-C-spall, Tb-p (42R52)
Dy^{156}		0.0524 (31[illegible]b)						
Dy^{158}		0.0902 (31[illegible]49b)						
Dy[illegible]	P chem, n-capt (24K49d); chem, cross bomb (65B51a)		EC (24K49d)	134 d (65B51a); 140 d (24K49d)		Tb K, L-x (65B51a)		Tb-d-2n (65B51a); Dy-n-γ (24K49d, 65B51a)

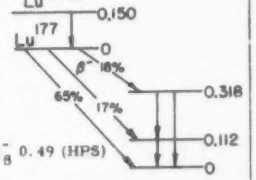
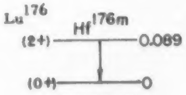
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{66}Dy^{160m}$	A genet (52M52)		IT (52M52a)	1.8×10^{-9} s delay coinc (52M52a)		0.085 (e_K/γ 1.7) scint spect (52M52a)		daughter Tb^{160} (52M52, 52M52a)
Dy^{160}		2.294 (3I49b)						
Dy^{161}		18.88 (3I49b)						
Dy^{162}		25.53 (3I49b)						
Dy^{163}		24.97 (3I49b)						
Dy^{164}		28.18 (3I49b)						
Dy^{165m}	A n-capt (9F44b); n-capt, sep isotopes (3I47e)		IT (9F44b)	1.25 m (9F46)		0.109 (K/L 0.08) spect conv (42C50); 0.102 scint spect (31K51); 0.102 spect conv (15H48)	 (1/2,13/2+) Dy^{165m} Dy^{165} 0.109 (7/2-) 0 β^- 0.76 0.36 (5/2+) 0.095 (7/2+) 0 (18G52)	Dy-n-γ (9F44b, 9F46, 2S47, 18G47, 42C50); Dy^{164}-n-γ (3I47e)
Dy^{165}	A n-capt (71H36, 82M35); n-capt, sep isotopes (3I47e); mass spect (3I47f)		β^- (1P38a)	139.2 m (109S52); 140 m (37B46); 145 m (5S46)	1.25, 0.88, 0.42 spect (5S46); others (72C42, 16D41, 10E41)	0.0951 (K/L_I 6.4) spect conv (63M52); 0.0878 spect conv (42C50); 0.091, 0.36, 0.76 spect, spect conv (5S46); others (43M46, 52M51, 52M52, 52W51)		Dy-n-γ (82M35, 71H36, 1P38a, 1M40, 2S47, 24K49d); Dy^{164}-n-γ (3I47e)
Dy^{166}	A chem, genet (24K49d)		β^- (24K49d)	82 h (65B50a); 81 h (24K49d)	0.2 abs (65B50a); 0.4 abs (24K49d)			Dy-n-γ (second order reaction) (24K49d, 65B50a); spall-fission U (6F51); parent Ho^{166} (24K49d, 65B50a)
$_{67}Ho$	E excit (42R52)		α (42R52)	4 m (42R52)	α: 4.2 ion ch (42R52)			Dy-p (42R52)
Ho^{160}	C excit (2W50c)		EC 99+%, β^+ ~0.5% (2W50c)	22.5 m (2W50c)	~1.3 abs (2W50c); conv: 0.2 abs (2W50c)	~1.2 abs (2W50c)		Tb-α-3n (2W50c)
Ho^{161}	B chem, excit (2W50c)		EC (2W50c)	4.6 h (2W50c)	conv: 0.1 abs (2W50c)	1.1 abs (2W50c)		Tb-α-2n, Dy-p-n, Dy-d-n (2W50c)
Ho^{162}	B chem, excit (2W50c)		EC ~85%, β^- ~15% (2W50c)	65.0 d (2W50c)	β^-: 0.8 spect, abs (2W50c); conv: 0.1 abs (2W50c)	~1 abs (2W50c)		Tb-α-n, Dy-p-n, Dy-d-2n (2W50c)
Ho^{163}	B chem, excit, cross bomb (2W50c)		EC (2W50c)	5.20 d (2W50c)	conv: 0.4 abs (2W50c)	~0.5, 1.4 abs (2W50c)		Dy-p-n, Dy-d-n, Dy-d-2n (2W50c)
Ho^{164}	A excit (1P38a)		β^- (2W50c)	34.0 m (2W50c); 41.5 m (25W50)	0.95 spect (2W50c)	no γ (2W50c)		Dy-p-n (2W50c); Ho-n-2n (1P38a, 25W50); Ho-γ-n (25W48)

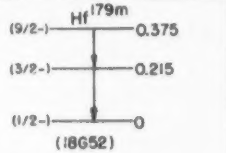
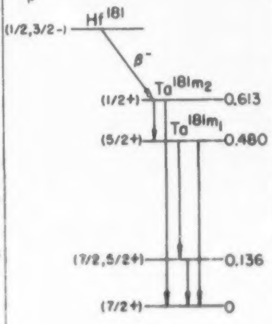
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{67}$Ho^{165}		100 (28L50)					Ho^{165}, I = 7/2 (87M50)	
Ho^{166}	A n-capt (71H36); mass spect (3I47d); chem (24K49b)		β^- (71H36)	27.3 h average of (24K49b, 3I47d, 37B46, 22G49, 10C49a, 31A50)	1.84 (~89%), 0.55 (~11%) spect (7S50a); 1.88 spect (22G49); 1.84 (86%), 0.66 (14%) spect (31A50); 1.85 spect (24K49); 1.90 cl ch, abs (97S50)	0.080 (e_K/γ 1.9, K/L+M 0.25), 1.38 (coinc with 0.08 γ) scint spect, γ-γ coinc (14S52a); 0.081 (K/L 0.07, $L_I/L_{II}/L_{III}$ = <0.1/0.72/1.00) spect conv (63M52); 0.080 (e_L/γ ~0.4, K/L <1), 1.36 (weak) spect, spect conv, β-conv coinc (7S50a); 0.081 (e_K/γ 1.9) scint spect (52M52a); 0.081, 0.9 spect conv, abs (10C49a); 0.081, ~1.5 (weak) spect conv, β-γ coinc (31A50); 0.080, 1.2 (weak) spect conv, abs (22G49)	 Ho^{166} (1-) ~55% β$^-$ ~11% ~34% 1.46 Er^{166m} (2+) (0+) 0.081 0 (14S52a)	Ho-n-γ (71H36, 1P38a, 1M40, 2S47); spall-fission U (6F51); daughter Dy^{166} (24K49d, 65B50a); parent Er^{166m} (52M50a, 52M52a, 63M52)
Ho^{166}	B chem, excit (65B52)		β^- (65B52)	>30 y (65B52)	1.1 (~8%), 0.28 (~46%), 0.18 (~46%) abs (65B52)	0.212 (coinc with 1.1 β), 0.280 (coinc with 0.73 and 0.83 γ), 0.725, 0.830, 0.095 (very weak) scint spect, γ-γ, β-γ coinc (65B52)		Ho-n-γ (65P52)
Ho^{167,169}	E excit (65B50)			96 m (65B50)				Er-γ-p (65B50)
$_{68}$Er^{160,161}	D chem (6F51)		β^+ (?) (6F51)	~17 h (6F51)				spall-fission U (6F51)
Er^{162}		0.136 (60H50)						
Er^{163}	D chem (6F51)		β^+ (?) (6F51)	~65 h (6F51)				spall-fission U (6F51)
Er^{164}		1.56 (60H50)						
Er^{165}	A chem, excit (65B50b); excit (29K52)		EC (65B50b)	10.0 h (65B50b); 9.9 h (29K52); 11.2 h (2W50d)	conv: ~0.2, 1.1 (weak) abs (29K52)	1.1 abs (2W50d); no γ (65B50b)		Dy-α-3n (2W50d); Ho-p-n (65B50b, 29K52); Ho-d-2n (29K52)
Er^{166m}	A genet (52M50a)		IT (52M50a)	1.7 x 10^{-9} s delay coinc (52M50a)		0.081 (e_K/γ 1.9) scint spect (52M52a); 0.081 (K/L 0.07) spect conv (63M52)	see Ho^{166}  (18G52)	daughter Ho^{166} (52M50a, 63M52, 52M52a)
Er^{166}		33.41 (60H50)						
Er^{167}		22.94 (60H50)					Er^{167}, I = 7/2 (97B51b)	
Er^{168}		27.07 (60H50)						
Er^{169}	E chem, n-capt (24K48)		β^- (24K48)	9.4 d (24K48); 9 d (65B50)	0.33 spect (24K48); 0.33 scint spect (11B49a)	no γ (24K48, 11K51)		Er-γ-n (65B50); Er-n-γ (24K48); spall-fission U (6F51)

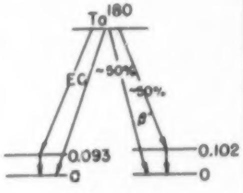
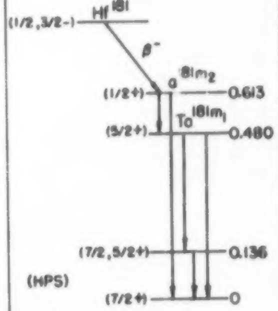
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{68}Er^{170}$		14. 88 (60H50)						
Er^{171}	B n-capt (71H36, 23N35); chem (24K48)		β^- (24K48)	7. 5 h (24K48, 11K51)	1. 49 (-6%), 1. 05 (-72%), 0. 67 (-22%) spect, β-γ coinc (24K48)	0. 113 (K/L -10), 0. 118 (K/L -0. 5), 0. 126 (K/L -2), 0. 176, 0. 295 (K/L -10), 0. 308 (K/L -10), 0. 420, no 0. 8 γ spect conv (11K51); 0. 113 (e/γ large, coinc with 1. 05 β and 0. 31 γ), 0. 31 (coinc with 1. 05 β), 0. 81 spect, spect conv, β-γ coinc (24K48); -0. 1 (e/γ 1. 3) β-γ delay coinc (10D48)		Er-n-γ (71H36, 1P38a, 24K48, 37B46, 23N35); parent Tm^{171} (24K48); parent Tm^{171m} (10D48)
Er^{m}	E n-capt (38M49a)		IT (38M49a)	2. 5 s (38M49a, 45G51)		0. 210 (e_K/γ 0. 55) scint spect (45G51, 24C51a)		Er-n-γ (38M49a, 45G51)
$_{69}Tm^{166}$	B chem, excit (2W49a)		EC 99+%, β^+ -0. 5% (2W49a)	7. 7 h (2W49a)	β^+: 2. 1 spect (2W49a); conv: 0. 24, -1 spect. abs (2W49a)	1. 7 abs (2W49a)		Ho-α-3n (2W49a); Er-p-n (2W49a); daughter Yb^{166} (6F51)
Tm^{167}	B chem, excit (2W49a)		EC, no β^+ (2W49a)	9. 6 d (2W49a)	conv: 0. 21 abs (2W49a)	0. 22, 0. 95 abs (2W49a)		Ho-α-2n (2W49a); Er-p-n (2W49a); spall Ta (2W49a)
Tm^{168}	A chem, excit (2W49a)		EC, β^- (?) -2% (2W49a)	85 d (2W49a)	conv: 0. 16, 0. 5 abs (2W49a)	0. 21, 0. 85 abs (2W49a)		Ho-α-n (2W49a); Er-p-n (2W49a); Tm-n-2n (2W49a)
Tm^{169m}	A genet (10D48)		IT (10D48)	all delay coinc: 0. 65 x 10^{-6} s (27F50); 0. 67 x 10^{-6} s (75M51a); 0. 7 x 10^{-6} s (52M51); 0. 60 x 10^{-6} s (14S51a)		see γ's of Yb^{169}		daughter Yb^{169} (10D48, 27F50, 52M51, 14S51a, 75M51a)
Tm^{169}		100 (71L50)					Tm^{169}, I = 1/2 (87M50)	
Tm^{170}	A n-capt (23N36, 71H36); chem (24K48a)		β^- (37B46a); no EC (lim 0. 3%), no β^+ (lim 0. 01%) (14G52)	129 d (24K49b); 120 d (42C50); 127 d (37B46a)	0. 968 (76%), 0. 884 (24%) spect (14G52); 0. 970 (-90%), 0. 886 (-10%) spect (36F49); 0. 970, 0. 88 spect, β-γ coinc (44R52); 0. 990 spect (16A50); others (14G49, 22G49a, 97S50, 9S49a)	0. 0841 (3%, e_K/γ 1. 6, K/L/M = 1/2. 6/0. 75) spect conv, β-γ coinc (14G52); γ (-3%, e/γ 9. 4, K/L+M 0. 22) x-γ coinc, scint spect (1N50); 0. 085 (K/L 0. 16, $L_I/L_{II}/L_{III}$ = <0. 1/0. 83/1. 00) spect conv (63M52); 0. 085 (e_K/γ 1. 5) scint spect (52M52a); 0. 084 (e/γ 4, K/L/M -1/6. 9/2. 1) spect, spect conv, β-γ coinc (36F49); γ (e/γ >10, K/L+M 0. 1) spect conv, scint spect (7S51); 0. 085 spect conv (16A50, 42C50, 9S49a); others (22G50a, 4E50a, 1N50a, 10C49a, 52R52)	Q^-_β 0. 970 (36F49)  Tm 170 (1-) β- 10% 90% Yb 170m (2+) (0+) 0.084 0 (18G52)	Tm-n-γ (71H36, 23N36, 2S47); Tm-d-p (24K48a); parent Yb^{170m} (8B50, 52M52a, 14G52)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{69}Tm^{171m}$	B genet (10D48)		IT (10D48)	2.5 x 10^{-6} s delay coinc (10D48)		0.113 (e/γ 1.3) spect conv, β-γ coinc (10D48); 0.113 (e/γ large) spect conv, β-γ coinc (24K48)		daughter Er^{171} (10D48)
Tm^{171}	B chem, genet (24K48)		$β^-$ (24K48)	680 d (24K49b)	0.10 spect (24K48a)			daughter Er^{171} (24K48)
$Tm^{172(?)}$	E chem (6F51)		$β^-$ (6F51)	2-3 d (6F51)				spall-fission U (6F51)
$Tm^{>171}$	E excit (65B50)			19 m (65B50)				Yb-γ-p (?) (65B50)
$_{70}Yb^{166}$	D chem, genet (6F51)		EC (6F51)	62 h (6F51)				spall-fission U, parent Tm^{166} (6F51)
Yb^{168}		0.140 (1B50)						
Yb^{169}	A n-capt (37B46a); chem, excit (24K48a)		EC (37B46a)	31.8 d (49W49); 32.4 d (10C50e); 33 d (37B46a, 75M51a)		$γ_1$ 0.023, $γ_2$ 0.064, $γ_3$ 0.095, $γ_4$ 0.110 (e/γ 1.6), $γ_5$ 0.120, $γ_6$ 0.133 (e/γ 0.2), $γ_7$ 0.143, $γ_8$ 0.160, $γ_9$ 0.178 (e/γ 0.8), $γ_{10}$ 0.198 (e/γ 0.4), $γ_{11}$ 0.308 (e/γ 0.04); ($γ_2/γ_4/γ_6/γ_9/γ_{10}/γ_{11}$ = 1.3/2.1/2.0/1.0/1.7/0.6) spect, spect conv, delay coinc (75M51a); 0.063, 0.094, 0.110, 0.131, 0.177, 0.198, 0.308 spect conv (10C50e); 0.109, 0.130, 0.177, 0.198, 0.307 scint spect, delay coinc (14S51a)		Tm-d-2n (24K48a); Yb-n-γ (34A45, 37B46a, 3148a); spall-fission U (6F51); parent Tm^{169m} (10D48, 27F50, 52M51, 14S51a, 75M51a)
Yb^{170m}	A genet (8B50)		IT (8B50)	1.57 x 10^{-9} s delay coinc (14G52); 1.6 x 10^{-9} s delay coinc (52M52a)		0.0841 (e_K/γ 1.6, K/L/M = 1/2.6/0.75) spect conv, β-γ coinc (14G52); 0.085 (e_K/γ 1.5) scint spect (52M52a)	see Tm^{170}  (18G52)	daughter Tm^{170} (8B50, 14G52, 52M52a)
Yb^{170}		3.03 (1B50)						
Yb^{171}		14.31 (1B50)					Yb^{171}, I = 1/2 (87M50)	
Yb^{172}		21.82 (1B50)						
Yb^{173}		16.13 (1B50)					Yb^{173}, I = 5/2 (87M50)	
Yb^{174}		31.84 (1B50)						
Yb^{175}	A n-capt (37B46a, 34A45); mass spect (3147f); chem (24K49b)		$β^-$ (34A45)	102 h (3147f); 99 h (37B46a); 101 h (34A45)	0.50, 0.13 abs (37B46a); 0.45 cl ch (34A45)	0.138, 0.259, 0.283, 0.396 spect conv (10C50e); others (52M51)		Yb-n-γ (34A45, 37B46a, 3147f, 24K49b); Yb-γ-n (65B50)
Yb^{176}		12.73 (1B50)						

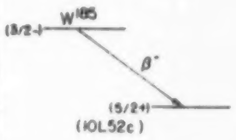
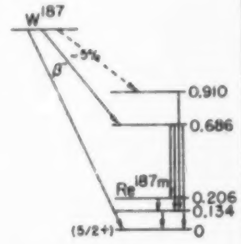
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{70}Yb^{177}$	B n-capt (82M35, 71H36); chem (24K49b)		β^- (37B46a)	1.8 h (52M51); 1.9 h (34A45); 2.4 h (37B46a)	1.3 abs (37B46a); 1.2 cl ch (34A45)	0.150 (K/L 3) spect conv, β-γ coinc (52M51)	 (18G52)	Yb-n-γ (82M35, 71H36, 1P38a, 37B46a, 3147f); parent Lu^{177m} (52M49, 52M51)
Yb^m	E n-capt (38M49a)		IT (38M49a)	6 s (38M49a, 31K51)		0.212, 0.104 (?) scint spect (31K51); 0.200 abs (38M49a); Yb K-x (38M49)		Yb-n-γ (38M49a, 38M49, 31K51)
Yb^m	E n-capt (38M49a)		IT (38M49a)	50 s (38M49a)		~ 0.025, Yb L-x abs (38M49a)		Yb-n-γ (38M49a, 38M49)
Yb^m	E n-capt (31K51)			0.15 s (31K52)		0.455 scint spect (31K52)		Yb-n-γ (31K51)
$_{71}Lu^{170}$	B chem, excit (2W51)		EC (2W51)	1.7 d (2W51)		~ 2.5 abs (2W51)		Tm-α-3n, spall Ta (2W51)
Lu^{171}	B chem, excit (2W51)		EC (2W51)	8.5 d (2W51)		~1.2 abs (2W51)		Tm-α-2n, Yb-p-n, spall Ta (2W51); daughter Hf^{171} (2W51)
Lu^{171}	D chem, excit (2W51)		EC (2W51)	~600 d (2W51)		~1 abs (2W51)		Tm-α-2n (2W51)
Lu^{172}	B chem, excit (2W51)		EC (2W51)	6.70 d (2W51)		1.2 abs (2W51)		Tm-α-n, Yb-p-n (2W51); daughter Hf^{172} (2W51)
Lu^{172}	B chem, excit (2W51)		β^+, EC (?) (2W51)	4.0 h (2W51)	1.2 abs (2W51)			Tm-α-n, Yb-p-n, Lu-p-p3n (2W51)
Lu^{173}	B chem, excit (2W51)		EC (2W51)	~500 d (2W51)		~ 0.2, 0.8 abs (2W51)		Yb-p-n, Lu-p-p2n (2W51); daughter Hf^{173} (2W51)
Lu^{174}	A chem, excit (2W51)		EC ~80%, β^- ~20% (2W51)	165 d (2W51)	β^-: 0.6 abs (2W51)	~1 abs (2W51)		Lu-n-2n, Lu-d-p2n, Lu-p-pn, Hf-d-α (2W51)
Lu^{175}		97.40 (60H50)					Lu^{175}, I = 7/2 (87M50)	
Lu^{176m}	A n-capt (77M35a, 82M35); chem, excit (2W48)		β^-, no IT (17S52)	3.67 h (34A45); 3.7 h (37B46a)	1.1, 1.2 (17S52); 1.3 cl ch (34A45); 1.2 abs (9F43)	0.0889 ($K/L_{II}/L_{III}$ = 0.24/0.71/1.00) spect conv (63M52); 0.089 (e_K/γ 1.3) scint spect, β-γ delay coinc (52M52c); 0.089 (e/γ large, K/L 0.1) scint spect (17S52)	 (1±) Lu^{176m} (≥7) Lu^{176} β^- 0.54 0.27 Hf^{176m} (2+) 0.089 (0+) 0 (18G52)	Lu-d-p (2W51, 2W48); Lu-n-γ (77M35a, 82M35, 71H36, 9F43, 37B46a, 34A45, 2S47, 24K49b, 31A50a); Lu-γ-γ (11D47a, 65B50); parent Hf^{176m} (52M52c)
Lu^{176}	A chem (52H38); mass spect (8M39)	2.60 (60H50)	β^-, no EC (17S52a)	7.5 x 10^{10} y sp act (3L39a)	0.40 abs (9F47a, 9F43)	0.089, 0.180, 0.270 scint spect (17S52a)	Lu^{176}, I ≥7 (87M50)	natural source (52H38, 8M39)

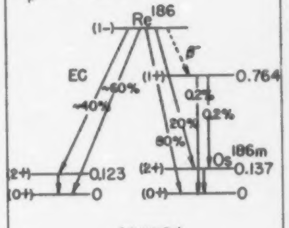
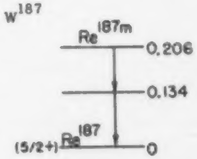
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{71}Lu^{177m}$	B genet (52M49)		IT (52M49)	1.3×10^{-7} s delay coinc (52M49, 52M51)		0.150 (K/L 3) scint spect, β-γ coinc (52M51, 52M49)	 Lu^{177m} 0.150 Lu¹⁷⁷ 0 β⁻ 18% 65% 17% 0.318 0.112 0 Q_{β}^{-} 0.49 (HPS) (18G52)	daughter Yb^{177} (52M49, 52M51)
Lu^{177}	A n-capt (71H36); mass spect (3147f); chem, excit (2W48)		β^- (37B46a)	6.8 d (37B46a, 2W48); 7.0 d (30D49); 6.6 d (9F43, 34A45)	0.495 (65%), 0.37 (17%), 0.17 (18%) spect (30D49); 0.475 spect (31A50a)	0.112 (e_K/γ 0.81), 0.206 (e_K/γ 0.04), 0.318 (~5%) scint spect, γ-γ coinc (52M52d); 0.112, 0.206, 0.317 (very weak) spect, spect conv (30D49); 0.112 (K/L/M ≈ 1/2/0.5), 0.205 spect conv (31A50a); 0.113, 0.209 spect conv (10C49a); others (52M51)		Lu-n-γ (71H36, 9F43, 34A45, 37B46a, 2S47, 24K49b, 31A50a); Lu-d-p (2W48)
$Lu^{178,179}$	D chem (65B50)			22 m (65B50)				Hf-γ-p (65B50)
$_{72}Hf^{170}$	D chem (2W51)		β^+ (2W51)	112 m (2W51)	2.4 spect (2W51)	no γ (2W51)		Lu-p-6n (2W51)
Hf^{171}	B chem, genet, excit (2W51)		EC (2W51)	16.0 h (2W51)		1.4 abs (2W51)		Yb-α-3n, Lu-p-5n (2W51); parent (8.5 d) Lu^{171} (2W51)
Hf^{172}	B chem, genet (2W51)		EC (2W51)	~5 y (2W51)		~0.28, 0.8 abs, spect conv (2W51)		Yb-α-2n, Yb-α-3n, Lu-p-4n, spall Ta (2W51); parent (6.7 d) Lu^{172} (2W51)
Hf^{173}	B chem, excit, genet (2W51)		EC (2W51)	23.6 h (2W51)		~1 abs (2W51)		Yb-α-n, Yb-α-2n, Yb-α-3n, Lu-p-3n (2W51); parent Lu^{173} (2W51)
Hf^{174}		0.18 (75H49)						
Hf^{175}	A chem, excit (2W49b); n-capt, sep isotopes (82B51); mass spect (12H51a)		EC (2W49b)	70 d (2W49b)		0.089, 0.113, 0.228, 0.318, 0.342 (K/L 4.9), 0.431 spect conv (82B52); 1.5 abs (2W49b)		Lu-d-2n, Lu-p-n (2W49b); Hf-n-γ (12H51a); Hf^{174}-n-γ (82B51)
Hf^{176m}	A genet (52M52c)		IT (52M52c)	1.35×10^{-9} s delay coinc (52M52c)		0.089 (e_K/γ 1.3) scint spect, β-γ coinc (52M52c)	see Lu^{176}  (52M52c)	daughter Lu^{176m} (52M52c)
Hf^{176}		5.15 (75H49)						
Hf^{177}		18.39 (75H49)					Hf^{177}, I = 1/2 or 3/2 (87M50)	
Hf^{178}		27.08 (75H49)					Hf^{178}, I = 0 (87M50)	

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{72}$Hf^{179m}	A n-capt (9F44b); n-capt, sep isotopes (82B51, 38M51b)		IT (9F46)	19 s (9F44b, 38M51b)		0.160, 0.217 scint spect, spect conv (82B51); ~0.150, 0.215 scint spect, conv-γ coinc (38M51b); 0.150 (e/γ very large, K/L 0.9) spect conv (15H48a); 0.220 scint spect (31K51)	 Hf^{179m} (9/2-) 0.375 (3/2-) 0.215 (1/2-) 0 (18G52)	Hf-n-γ (9F44b, 9F46, 38M51); Hf^{178}-n-γ (38M51b, 82B51)
Hf^{179}		13.78 (75H49)					Hf^{179}, I = 1/2 or 3/2 (87M50)	
Hf^{180m}	B chem, n-capt, sep isotopes (82B51)		IT (82B51)	5.5 h (82B51)		0.057, 0.093, 0.214, 0.330, 0.442 spect conv, γ-conv coinc (82B51)		Hf^{179}-n-γ (82B51)
Hf^{180}		35.44 (75H49)					Hf^{180}, I = 0 (87M50)	
Hf^{181}	A chem, n-capt (71H38); mass spect (12H51a); sep isotopes, n-capt (82B51)		β^- (71H38)	45 d (10C50f, 22P50); 47 d (43B48a)	0.408 spect (29F52); 0.420 spect (82B51); 0.410 spect (4E50); 0.404 spect (71C49); 0.460 spect (43B48a)	γ_1 0.133, γ_2 0.136, γ_3 0.344, γ_4 0.481, γ_5 0.611 spect conv, β-conv, conv-conv, β-γ coinc (82B51); γ_1 0.133, γ_2 0.136, γ_3 0.345, γ_4 0.481, γ_5 0.615 spect conv (4E50); γ_1 0.133 (K/L ~1), γ_2 0.136 (K/L ~0.2), γ_3 0.345, γ_4 0.481, γ_5 0.612 (γ_1 and γ_2 coinc with γ_3, γ_1 coinc with γ_4, γ_4 not coinc with γ_3) spect conv, conv-conv coinc (10C50f); γ_0 (e_K/γ 0.51), γ_4 (e_K/γ 0.034) scint spect, γ-γ coinc (52M52e); γ_1 0.130 (e/γ 0.90, K/L+M 0.6), γ_2 0.134 (e/γ ~3, K/L+M ~8), γ_3 0.340 (e/γ ~0.4), γ_4 0.474 (e/γ 0.030, K/L+M 4.0) spect conv (29F52); γ_1 0.132, γ_2 0.135 (K/L ~8), γ_3 0.345, γ_4 0.481 (γ_1/γ_2 ~5, γ_4/γ_3 ~8) spect, spect conv (12H51a); γ_1 0.130 (e_K/γ ~1.3), γ_2 0.134, γ_3 0.337 (K/L ~3.6), γ_4 0.471 (K/L ~3) (γ_3/γ_4 ~2.5) spect conv, β-γ, conv-conv coinc (71C49); γ_3 0.347 (K/L ~5.0), γ_4 0.485 (K/L ~5.2) spect, spect conv (13J49a); others (43B48a, 10C47, 24N47, 3V48, 26M49a, 49W49a, 63B50, 20D50a, 32P50, 27F50a, 35F50, 52M51, 4B48, 4B49, 14L49)	Q_β^- 1.02 (HPS)  Hf^{181} (1/2,3/2-) β^- Ta^{181m_2} (1/2+) 0.613 Ta^{181m_1} (5/2+) 0.480 (7/2,5/2+) 0.136 (7/2+) 0 (HPS)	Hf-n-γ (71H38, 2S47); Hf^{180}-n-γ (82B51); Ta-n-p (24N47); spall-fission U (6F51); parent Ta^{181m_1} (4E50, 63B50, 52M51); parent Ta^{181m_2} (10D48, 4B48, 4E50, 63B50, 52M51)
Hf^{m}	E (24C52)		IT (24C52)	~3.5 s (24C52)				Hf-n (24C52)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma transitions		
${}_{73}Ta^{176}$	B chem, excit (2W48, 2W50e)		EC (2W50e)	8.0 h (2W50e)	conv: 0.1, 0.2, -1 abs (2W50e)	-2 abs (2W50e)		Lu-α-3n (2W50e); spall Ta (2W48); daughter W^{176} (2W50e)
Ta^{177}	B chem, excit (2W48, 2W50e)		EC (2W50e)	53 h (2W50e)	conv: 0.1 abs (2W50e)	-1.4 (weak) abs (2W50e)		Lu-α-2n, Lu-α-3n, Hf-p-n (2W50e); spall Ta (2W48); daughter W^{177} (2W50e)
Ta^{178}	B chem, excit (2W50e)		EC -97%, β^+ -3% (2W50e)	2.1 h (2W50e)	β^+: -1 abs (2W50e); conv: -0.1 abs (2W50e)	1.3-1.5 abs (2W50e)		Lu-α-n, Hf-p-n, Ta-p-p3n (2W50e)
Ta^{178}	B chem, genet (2W50e)		EC -94%, β^+ -6% (2W50e)	9.35 m (2W50e)	β^+: 1.06 spect (2W50e); conv: 0.08 spect conv (2W50e)	-1.5 abs (2W50e)		Hf-p-n (2W50e); daughter W^{178} (2W50e)
Ta^{179}	D chem, excit (2W50e)		EC (2W50e)	-600 d (2W50e)	conv: -0.1 abs (2W50e)	-0.7 (weak) abs (2W50e)		Lu-α-n, Hf-p-n, Ta-p-p2n (2W50e)
Ta^{180}	A chem, excit (17O38)		EC -79%, β^- -21%, no β^+ (lim 0.005%) (95B51)	8.15 h (95B51); 8.00 h (2W50e); 8.2 h (17O38)	0.71 (-50%), -0.61 (-50%) spect (95B51); 0.7 spect (2W50e); abs (83M51)	γ_1 0.093 (K/L -0.15), γ_2 0.102 (γ_1 + γ_2: e/γ -5), γ_3 0.2, γ_4 0.4 (γ_3 and γ_4 very weak) spect conv, scint spect, β-γ, x-γ coinc (95B51); 1.3 abs (2W50e)	 Ta180 EC -50% -50% β- 0.093 0 0.102 0 (95B51)	Ta-n-2n (1P37, 17O38, 2W50e); Ta-γ-n (27M49, 55B51, 95B51); Ta-p-pn (96B49, 2W50e); W^{182}-γ-pn (83M51)
Ta^{181m_2}	A genet (10D48)		IT (10D48)	2.2 x 10^{-5} s delay coinc (10D48, 4E50, 63B50); 2.0 x 10^{-5} s delay coinc (4B48)		see γ's of Hf^{181}	 Hf181 (1/2,3/2-) β- Ta181m2 (1/2+) 0.613 Ta181m1 (5/2+) 0.480 (7/2,5/2+) 0.136 (HPS) (7/2+) 0	daughter Hf^{181} (10D48, 4B48, 4E50, 63B50, 52M51)
Ta^{181m_1}	A genet (63B50)		IT (63B50)	1.2 x 10^{-8} s delay coinc (4E50); 1.1 x 10^{-8} s delay coinc (63B50); 1 x 10^{-8} s delay coinc (52M51)		see γ's of Hf^{181}		daughter Hf^{181} (4E50, 63B50, 52M51)
Ta^{181}		100 (24W48)					Ta^{181}, I = 7/2 (87M50)	
Ta^{m}	E n excit (24C49, 24C52)		IT (45G50)	0.33 s (24C49, 45G50, 31K51)		Ta L-x (45G50, 31K51)		Ta-n (24C49, 45G50, 31K51)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{73}Ta^{182m}$	A chem, n-capt (2S47, 15H48a)		IT (15H48a); IT ~95%, β^- ~5% (2W50e)	16.5 m (15H48a) 16.2 m (2S47)	β^-: 0.6 abs (2W50e)	0.180 (K/L 0.25) spect conv (15H48a); 0.180 (e_K/γ 0.8) scint spect (14S51)		Ta-n-γ (2S47, 15H48a, 2W50e)
Ta^{182}	A chem, n-capt (37F36, 17O38)		β^- (76H40)	111 d (21E52, 38S51); 113 d (9S49c); 117 d (2S47, 11Z43)	0.525, other β's, spect (7J49); 0.53 spect (86B49a); others (11R47, 7J47, 24N47)	γ_1 0.065714, γ_2 0.067736, γ_3 0.084667, γ_4 0.10009, γ_5 0.11366, γ_6 0.11640, γ_7 0.15241, γ_8 0.15637, γ_9 0.17936, γ_{10} 0.19831, γ_{11} 0.22205, γ_{12} 0.22927, γ_{13} 0.26409, γ_{14} 1.121, γ_{15} 1.188, γ_{16} 1.223 (rel intens: γ_1 9, γ_2 100, γ_3 6, γ_4 46, γ_5 9, γ_6 2, γ_7 43, γ_8 14, γ_9 19, γ_{10} 9, γ_{11} 45, γ_{12} 24, γ_{13} 27, γ_{14} 352, γ_{15} 157, γ_{16} 334) cryst spect (100M52); 0.046, 0.058, 0.065, 0.067, 0.075, 0.077, 0.084, 0.100, 0.113, 0.134, 0.143, 0.152, 0.178, 0.198, 0.221, 0.228, 0.245, 0.262 spect conv (10C50e); 1.121, 1.189, 1.219 spect, spect conv (10C51e); 0.082, 0.098, 0.112, 0.122, 0.132, 0.141, 0.157, 0.165, 0.172, 0.198, 0.222, 0.243, 0.255, 0.264, 0.290 (?), 0.299 (?), 0.324, 1.133, 1.219, 1.237 spect, spect conv (86B49a); 0.224, 0.232, 0.260, 0.268, 0.280, 0.320, 0.342, 0.362, 0.392, 0.412, 0.421, 0.526, 0.565, 0.607, 0.624, 0.728, 0.763, 0.780, 0.892, 0.935, 0.993, 1.133, 1.215, 1.231 spect (18O50); others (4G49, 11R47, 10C49b, 13E50, 94S50, 98S48, 4B49, 52M51, 52W51)		Ta-n-γ (37F36, 17O38, 76H40, 2S47, 1M48); Ta-d-p (17O38, 11Z43, 31S50); W-d-α, W-n-p (33T51)
Ta^{183}	B chem, excit (65B50)		β^- (2W50f)	5.2 d (65P52c); 6.0 d (83M51); 6.1 d (2W50f)	0.65 scint spect (65P52c); 0.6 abs (2W50f, 83M51)	0.24 scint spect (65B52c); γ (2W50f)		W-n-p (2W50f, 65B52c); W-γ-p (65B50, 83M51)
Ta^{184}	? chem, excit (65P52c)		β^- (65B52c)	9.3 h (65B52c)	1.4 abs (65B52c)	0.410, 0.86, 1.10 scint spect (65B52c)		W-n-p, W^{184}-n-p (65B52c)
Ta^{185}	A chem, excit (65B50); excit, sep isotopes (23D50)		β^- (23D50)	48 m (83M51, 65B50)	1.6, 0.15 (conv?) abs (83M51); 1.7 abs (23D50)			W-γ-p (65B50, 83M51); W^{186}-γ-p (23D50)
$_{74}W^{176}$	B chem, genet (2W50e)		EC 99+%, β^+ ~0.5% (2W50e)	80 m (2W50e)	β^+: ~2 abs (2W50e); conv: ~0.1, ~0.2 abs (2W50e)	~1.3 abs (2W50e)		Ta-p-6n (2W50e, 22N52); parent Ta^{176} (2W50e)
W^{177}	B chem, genet (2W50e)		EC (2W50e)	130 m (2W50e)	conv: 0.13, ~0.4 abs (2W50e)	~0.5, 1.2 abs (2W50e)		Ta-p-5n (2W50e, 22N52); parent Ta^{177} (2W50e)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{74}W^{178}$	B chem, genet (2W50e)		EC (2W50e)	21.5 d (2W50e)		~0.3 (weak) abs (2W50e)		Ta-p-4n (2W50e, 22N52); parent 9.4 m Ta^{178} (2W50e)
W^{179}	D chem, excit (2W50e)		EC (2W50e)	30 m (2W50e)				Ta-p-3n (2W50e)
W^{179}	D chem, excit (2W50e)		EC or IT (2W50e)	~ 2 m (2W50e)				Ta-p-3n (2W50e)
W^{180}		0.135 (9W46)						
W^{181}	A chem, excit (2W47); chem, n-capt (37L51)		EC (2W47)	140 d (2W47)		0.030, 0.600, 0.800 scint spect (13A50b); 1.8 (weak) abs (2W47)		Ta-d-2n (2W47); Ta-p-n (96B49); W-n-γ (13A50b, 37L51); not parent Ta^{181m_3} (38M51c)
W^{182}		26.4 (9W46)					W^{182}, I = 0 (87M50)	
W^{183m}	B sep isotopes, n-capt (38M49)		IT (38M49)	5.5 s (38M49, 24C52a)	conv: 0.08 abs (38M49a)	0.12, 0.17 scint spect (24C52a)		W^{182}-n-γ (38M49); W-n-γ (38M49, 31K51)
W^{183}		14.4 (9W46)					W^{183}, I = 1/2 (87M50)	
W^{184}		30.6 (9W46)					W^{184}, I = 0 (87M50)	
W^{185m}	C excit, sep isotopes (23D50)		IT (23D50)	1.85 m (23D50)	conv: 0.075 scint spect (23D50)		 (10L52c)	W^{186}-γ-n (23D50)
W^{185}	A chem, excit, n-capt (64M40)		β⁻ (64M40)	73.2 d (9S48a); 75 d (5F40a)	0.428 spect (68S48); 0.43 spect (20P48, 9S48a); others (23S45a)	no γ (10L52c, 23S45a, 65C47a); others (10C49, 4B49, 52M51)		W-n-γ (64M40, 5F40a, 2S47, 10C49); W-n-2n (64M40, 5F40a); W-d-p (5F40a); Re-d-α (5F40a)
W^{186}		28.4 (9W46)					W^{186}, I = 0 (87M50)	
W^{187}	A chem, n-capt (12A35); chem, n-capt, excit (64M40)		β⁻ (64M40)	24.1 h (5F40a); 24.0 h (64M40)	1.33 (30%), 0.63 (70%) spect (20P48); 1.32 (≥12%), 0.63 (≥65%), ~0.38 (≤23%) spect (2L49); 1.34, ~0.65 spect (15H48b); others (23S45a, 43M46)	0.07200, 0.13425, 0.4795, 0.6189, 0.6861 cryst spect (100M52); γ_1 0.072 (coinc with γ_2, delay coinc with γ_3), γ_2 0.134 (coinc with γ_1, γ_4, and γ_7, delay coinc with γ_3), γ_3 0.48 (e_K/γ 0.022, delay coinc with γ_1 and γ_2, not coinc with γ_4 or γ_6), γ_4 0.552 (coinc with γ_2), γ_5 0.618 (not coinc with other γ's), γ_6 0.69, γ_7 0.775 (coinc with γ_2) ($\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7$ = 0.45/1.00/0.31/0.42/1.48/0.23) scint spect (14S52a); 0.133, 0.204, 0.478, 0.615, 0.680, 0.767 spect conv (2L49); 0.129, 0.462, 0.652 spect conv, β-γ, γ-γ coinc (15H48b); 0.078, 0.138 spect conv (86B49b); others (6V41a, 72C42, 20P48, 9J51)	Q_β^- 1.33 (HPS)  W^{187} ~5% β⁻ 0.910 0.686 Re^{187m} 0.206 0.134 (5/2+) 0 (14S52a)	W-n-γ (12A35, 77M35b, 64M40, 5F40a, 2S47, 10C49); W-d-p (5F40a, 20P48); spall U (6O48); parent Re^{187m} (10D48, 4F49, 52M51)
W^{188}	A chem, genet (37L51)		β⁻ (37L51)	65 d genet (37L51)				W-n-γ (second order reaction) (13A50c, 37L51, 37L51a); parent Re^{188} (37L51, 37L51a)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
${}_{75}$Re^{182}	B chem, excit (2W50g); chem, sep isotopes (31D50)		EC (2W50g)	12.7 h (2W50g); 14 h (31D50)		0.110, 0.127, 0.222, 0.250, 0.346 spect conv, spect (2W50g)		Ta-α-3n (2W50g); W-p-n (2W50g); W^{182}-d-2n (31D50); daughter Os^{182} (93S50)
Re^{182}	D (182) chem, excit (2W50g); (183) chem, sep isotopes (31D50)		EC (2W50g)	64.0 h (2W50g); 67 h (31D50)		0.110, 0.127, 0.222, 0.250, 0.346 spect conv, spect (2W50g)		Ta-α-3n, W-p-n (2W50g); W^{182}-d (31D50)
Re^{183}	B chem, excit (2W50g)		EC (2W50g)	155 d (33T51); 120 d (93S50)		0.081, 0.252 spect conv (2W50g)		Ta-α-2n, W-p-n (2W50g); W-d-n, W-α-p (33T51); daughter Os^{183} (93S50)
Re^{184}	A chem, excit (5F40a); chem, excit (2W50g)		EC (2W50g)	50 d (2W50g, 33T51)		0.159, 0.206, 0.244, 0.784, 0.89 spect conv (4W52); 0.043, 0.159, 0.205, 0.285 spect, spect conv (2W50g); 1.0 abs (33T51, 29C40)		Ta-α-n (2W50g); W-α-pn (33T51); W-p-n (2W50g); W-d-n (29C40, 5F40a, 33T51); Re-n-2n (2W50g, 5F40a)
Re^{184}	B chem, excit (2W50g)		EC or IT (2W50g)	2.2 d (2W50g)		0.043, 0.159 spect, spect conv (2W50g)		Ta-α-n (2W50g); W-p-n (2W50g)
Re^{185}		37.07 (24W48)					Re^{185}, I = 5/2 (87M50)	
Re^{186}	A n-capt (8K35); n-capt, excit (99S39); chem, n-capt, excit (5F40a); mass spect (43H47)		β^- ~95%, EC ~5%, no β^+ (lim 10^{-5}%) (44M51); β^- ~91%, EC ~9% (82S51a)	92.8 h (24G47b); 91 h (10C48); 90 h (99S39)	1.07 (80%), 0.93 (20%) spect (44M51); 1.070 (73%), 0.942 (27%) spect (82S51a); 1.090 (67%), 0.95 (30%), 0.64 (3%) spect (22G49a); 1.063 spect (10L49); 1.07 spect (86B49a)	with β^-: γ_1 0.137 (e_K/γ ~0.35, K/L/M = 0.6/1/0.2), 0.627, 0.764 spect, spect conv, β-γ, γ-γ coinc (44M51); γ_1 0.136 (e_K/γ 0.37, K/L/M = 0.6/1/0.2) spect, spect conv, β-conv, γ-γ coinc (82S51a); with EC: γ_2 0.123 (~2%), γ_1/γ_2 = 9 (44M51); γ_2 0.122 (3%, e_K/γ 0.45, K/L 0.6) (82S51a); others (22G49a, 10C48, 86B49a)	Q_β^- 1.07 (44M51)  Re^{186} (1-) EC ~60% ~40% β^- (1+) 0.764 0.2% 0.2% 20% 80% Os^{186m} (2+) 0.123 (0+) 0 (2+) 0.137 (0+) 0 (44M51)	W-d-2n (5F40a); W-p-n (29C40); Re-γ-n (12P48); Re-n-γ (8K35, 99S39, 5F40a, 8Y40, 2S47); Re-n-2n (99S39, 8Y40, 5F40a); Re-d-p (5F40a, 66C50); spall Re (66C50); parent Os^{186m} (52M51a)
Re^{187m}	A genet (10D48)		IT (10D48)	5.3×10^{-7} s delay coinc (4B49); 5.5×10^{-7} s delay coinc (52M51)		0.133 (e_K/γ ≤3.2, K/L ~5) scint spect (52M52b); see γ's of W^{187}	see W^{187} 	daughter W^{187} (10D48, 4B49, 52M51)
Re^{187}	A chem (25N48)	62.93 (24W48)	β^- (25N48)	4×10^{12} y sp act (25N48, 63S48)	0.400 ion ch (42D52); 0.043 abs (25N48)	no γ, no x (42D52)	(14S52a) Re^{187}, I = 5/2 (87M50)	natural source (25N48, 63S48)

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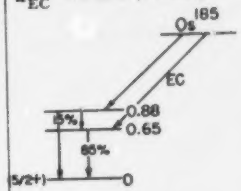
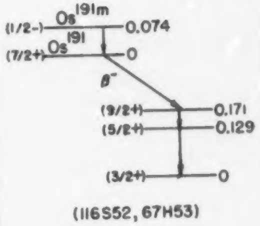
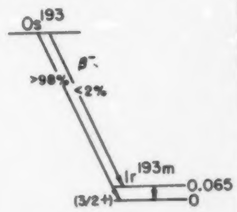
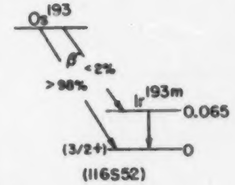
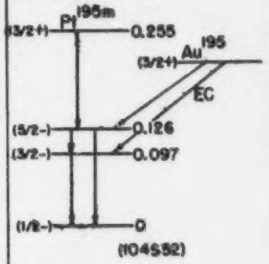
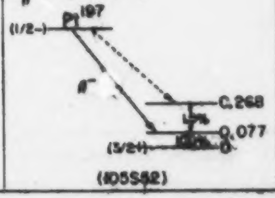
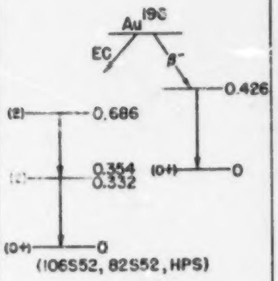
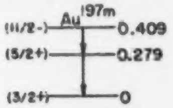
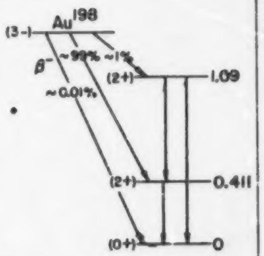
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{75}Re^{188m}$	C n-capt, sep isotopes (63M52d, 63M52b)		IT (63M52d)	22 m (63M52d); 17 m (65B50)		0.0635, 0.092, 0.104 spect conv, scint spect (63M52b)		Re^{187}-n-γ (63M52b); Os-γ-p (?) (65B50)
Re^{188}	A chem, n-capt (12A35); n-capt, excit (99S39); chem, n-capt, excit (5F40a); mass spect (43[illegible]47)		β^- (99S39)	16.9 h (37L51); 18.9 h (24G47); 18 h (1P37)	2.07 (coinc with 0.152 γ) spect, β-γ coinc (44R52a); 2.10 spect (86B49a); 2.05 abs (24G47); others (26M48b, 99S39)	0.152 (70%, e_K/γ 0.05, [illegible] 0.42), 0.476 (3%), 0.638 (6%), 0.933 (5%), 1.3 (5%) spect, abs, spect conv (44R52a); 0.15, 0.48, 0.64, 0.95, 1.40 spect (86B49a); 0.16, 0.48, 0.64, 0.94, 1.43 spect (43M46); 1.39 coinc abs (26M48b); 0.154 spect conv (10C48)		Re-n-γ (8K35, 12A35, 1P37, 99S39, 5F40a, 8Y40, 2S47); Re-d-p (5F40a, 24G47, 66C50); spall U (6O48); spall Re (66C50); daughter W^{188} (37L51, 37L51a)
Re^{189}	D chem (37L51, 33T51)		β^- (37L51, 33T51)	150 d (37L51); 250-300 d (33T51)	0.2 abs (37L51, 33T51)	1.0 abs (33T51)		W-α-p (33T51); Re-n-γ (second order reaction) (37L51)
Re	E chem (37L51)		β^- (37L51)	≥5 y (37L51)	0.75 abs (37L51)			Re-n-γ (second order reaction) (?) (37L51)
$_{76}Os^{182}$	B chem, genet (93S50)		EC, no β^+ (93S50)	24.0 h (93S50)				Re-p-4n (93S50); parent Re^{182} (93S50)
Os^{183}	B chem, genet (93S50)		EC (93S50)	12.0 h (93S50)	conv: 0.15, 0.42 spect conv (93S50)	0.3, 1.6 abs (93S50)		Re-p-3n (93S50); parent Re^{183} (93S50)
Os^{184}		0.018 (6N37a)						
Os^{185}	B chem, cross bomb (24G47, 50K48)		EC (L/K ~0.35) (69M51a); no β^+ (2B50b)	97 d (50K48, 33T51); 95 d (24G47)		γ_1 0.648, γ_2 0.878 (γ_1/γ_2 ~6) spect, γ-γ coinc (2B50b); γ_1 0.65, γ_2 0.88 (γ_1/γ_2 6.1) scint spect (69M51b); 0.235, 0.653 spect conv (116S52)	Q_{EC} ~1.0 calc (69M51a)  Os^{185} EC 0.88 0.65 5% 85% (5/2+) 0 (2B50b, 69M51b, HPS)	Re-d-2n (24G47, 66C50); Re-p-n (93S50); Os-n-γ (50K48)
Os^{186m}	A genet (52M51a)		IT (52M51a)	8×10^{-10} s delay coinc (52M51a)		0.137 scint spect (52M51a)	see Re^{186}	daughter Re^{186} (52M51a)
Os^{186}		1.59 (6N37a)						
$Os^{187m(?)}$	E chem (66C50)			35 h (66C50)				daughter Ir^{187} (?) (66C50)
Os^{187}		1.64 (6N37a)						
Os^{188}		13.3 (6N37a)						

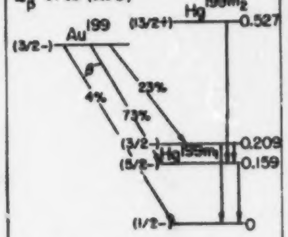
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{76}Os^{189}$		16.1 (6N37a)					Os^{189}, I = 1/2 (87M50)	
Os^{190m}(?)	E chem (66C50)			6 h (66C50)				daughter 12 d Ir^{190} (?) (66C50)
Os^{190m}	D chem, genet (66C50)			9.5 m (66C50)				daughter 3 h Ir^{190} (66C50)
Os^{190}		26.4 (6N37a)						
Os^{191m}	A chem, genet (116S52)		IT, no β^- (lim 5%) (116S52)	14 h (116S52)		0.0742 ($L_I/L_{II}/L_{III}$ = 42/24/100) spect conv (116S52)	 Os 191m 191 (1/2-) 0.074 (7/2+) 0 β⁻ (9/2+) 0.171 (5/2+) 0.129 (3/2+) 0 (116S52, 67H53)	Os-n-γ, Os-γ-n, parent Os^{191} (116S52)
Os^{191}	A n-capt (12Z40); chem, n-capt (13S41b); chem, excit (23F48a, 116S52)		β^- (13S41b)	16.0 d (66C50); 16.1 d (9S48a); 15.0 d (50K48)	0.143 spect (38K51b); 0.142 spect (9S48a); others (50K48, 13S41b, 37W47, 26M48b, 2B50b)	γ_1 0.0417 (L_{II}/L_{III} = 32/40, e/γ large), γ_2 0.129 (coinc with γ_1, $K/L_I/L_{II}/L_{III}$ = 100/30/11/6) spect conv, conv-conv coinc (116S52); γ_1 (e_K/γ 1.36) (116S52, calc from 38K51b); 0.042 (L/M 1.8), 0.128 (e_K/γ ~0.5, K/L 2.1) spect conv (38K51b, 38K51c); 0.041, 0.128 spect conv, spect (2B50b); 0.039, 0.127 spect conv (9S48a); 0.129 spect conv (10C47)	Q^-_β 0.313 (38K51b)	Os-n-γ (13S41b, 12Z40, 2S47, 116S52); Os-d-p (66C50); Os-γ-n (23F48a, 116S52); spall U (6O48); daughter Os^{191m} (116S52)
Os^{192}		41.0 (6N37a)						
Os^{193}	A n-capt (8K35, 12Z40); chem, n-capt (13S41b); chem, excit (23F48a, 116S52)		β^- (13S41b)	30.6 h (66C50); 31.9 h (24G47); 32 h (13S41b); 30 h (12Z40)	1.10 spect (2B50b); 1.05 scint spect (52M50b); 1.15 abs (66C50, 26M48b)	with Ir^{193m}: 0.066 spect conv (116S52); 0.065 scint spect, β-γ delay coinc (52M50b); no γ (2B50b); others (24G47, 26M48b)	Q^-_β 1.17 (HPS)  Os 193 β⁻ >98% <2% Ir 193m 0.065 (3/2+) 0 (116S52)	Os-n-γ (8K35, 12Z40, 13S41b, 2S47); Os-d-p (24G47, 66C50); Ir-d-2p (24G47); spall U (6F51); parent Ir^{193m} (52M50b, 52M51); not found: Os-γ-n (23F48a, 116S52)
Os^{194}	A chem, genet (37L50a)		[β^-] (37L50a)	~700 d (37L51)				Os-n-γ (second order reaction) (37L50a, 37L51); parent Ir^{194} (37L50a, 37L51)
$_{77}Ir^{187}$	B chem, excit, sep isotopes (66C50)		EC 99+%, β^+ ~0.2% (66C50)	11.8 h (66C50)	β^+: 2.2 spect (66C50); conv: 0.3, 1.2 spect conv (66C50)	~1.3 abs (66C50)		Re-a-2n, Re^{185}-a-2n (66C50); Os-d-3n (66C50); parent Os^{187m} (?) (66C50)
Ir^{188}	B chem, excit, sep isotopes (66C50)		EC 99+%, β^+ ~0.3% (66C50)	41.5 h (66C50)	β^+: 2.0 spect (66C50); conv: 0.2, 0.9 spect conv (66C50)	~1.8 abs (66C50)		Re-a-n, Re-a-3n, Re^{187}-a-3n (66C50); Os-d-2n, Os-d-3n (66C50)

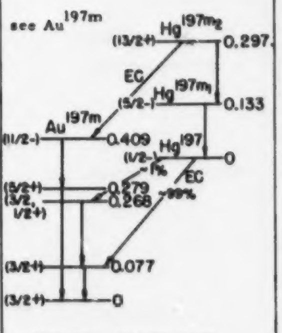
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{77}Ir^{190}$	D chem, excit, sep isotopes (66C50)		β^+, EC (?) (66C50)	3.2 h (66C50)	β^+: 1.7 spect (66C50); conv: 0.2, 0.8 spect conv (66C50)			Re-α-n, Re^{187}- n (66C50); Os-d-n, Os-d-2n (66C50); parent 9.5 m Os^{190m} (66C50)
Ir^{190}	B chem, excit (24G47); chem, excit, sep isotopes (66C50)		EC (24G47)	12.6 d (66C50); 10.7 d (24G47)		0.2, 0.6 abs (66C50); 0.3 abs (24G47)		Re-α-n, Re^{187}-α-n (66C50); Os-d-n (24G47, 66C50); Ir-n-2n (24G47); parent 6 h Os^{190m} (?) (66C50)
Ir^{191}		38.5 (37S36a)					Ir^{191}, I = 3/2 (99B50); Ir^{191}, I = 1/2 (94B49)	
Ir^{192m}	A n-capt (12M37); resonance neutron activation (18G47a)		IT (18G47a)	1.42 m (15H48a); 1.5 m (12M37)		0.057 spect conv (42C50); 0.056 spect conv (15H48a); γ (continuum) scint spect (38M51); γ (e_L/γ >400) ion ch (31K51)		Ir-n-γ (12M37, 18G47a, 2S47)
Ir^{192}	A n-capt (12A36); mass spect (37R46); chem (2W48a)		EC, β^- (10C51f); no β^+ (lim 0.008%) (41M51)	74.37 d (51K51); 74.5 d (38S51); 74.7 d (66C50)	0.66 spect (88S51a); 0.67 spect (2L47); 0.68 coinc abs (37W47); 0.6 abs (26M48a, 24G47)	γ_1 0.13633, γ_2 0.20131, γ_3 0.20574, γ_4 0.29604, γ_5 0.30845, γ_6 0.31646, γ_7 0.46798, γ_8 0.4848, γ_9 0.5884, γ_{10} 0.6045, γ_{11} 0.6129 (rel abund γ_1 4, γ_2 10, γ_3 75, γ_4 380, γ_5 370, γ_6 990, γ_7 300, γ_8 11, γ_9 11, γ_{10} 14, γ_{11} 5) cryst spect (100M52); 0.136, 0.151 (or 0.156), 0.169 (or 0.173), 0.201, 0.206, 0.283, 0.295, 0.308, 0.316, 0.396 (or 0.400), 0.415, 0.434 (or 0.438), 0.467, 0.484, 0.589, 0.604, 0.611 spect conv (10C51f); 0.775, 0.870 scint spect (50R52); others (103S51, 2L47, 20D50, 4B49, 67H48b, 52W51, 98S48, 56G49, 88S51a, 52M51)	Q_{β}^- 1.58 (50R52)	Os-d-2n (24G47, 66C50); Ir-n-γ (12A36, 12M37, 24J38, 2S47); Ir-n-2n (24G47); Ir-d-p (24G47, 2W48a); Pt-d-α (2W48a); Pt-γ-pn (25C52)
Ir^{193m}	B genet (52M50b)		IT (52M50b)	5.7 x 10^{-9} s delay coinc (52M50b)		0.065 scint spect, β-γ delay coinc (52M50b)	 Os^{193} β^- <2% >90% Ir^{193m} 0.065 (3/2+) 0 (116S52)	daughter Os^{193} (52M50b, 52M51)
Ir^{193}		61.5 (37S36a)					Ir^{193}, I = 3/2 (99B50, 94B49)	
Ir^{194}	A n-capt (12A35); mass spect (37R46); chem (2W48a)		β^- (12M37)	19.0 h (24G47); 19.5 h (53W41); 19 h (12A35, 12M37)	2.18 spect (53W41); 2.2 spect (24A36); 2.1 abs (53W41, 24G47); 0.5 β-γ coinc abs (26M48a)	γ_1 0.290, γ_2 0.326, γ_3 1.51 ($\gamma_1/\gamma_2/\gamma_3$ = 1/5/1) spect (89B52); 0.328 spect conv (10C51f); 1.7-2.2 (0.14%) Be, D-γ-n reaction (23W50); others (4B49, 26M48a, 42C50, 37L51)		Ir-n-γ (12A35, 1P37, 2S47, 12M37, 24J38); Ir-d-p (24G47, 2W48a); Pt-γ-p, Pt-γ-pn (25C52)
Ir^{195}	D chem, excit (25C52)		β^- (25C52)	140 m (25C52, 65B52b)	1.8 abs (65B52b); ~1 abs (25C52)	0.49, 0.84 scint spect (65B52b)		Pt-γ-p (25C52); Pt-n-p (65B52b)
Ir^{196}	D chem, excit (65B52b)		β^- (65B52b)	9 d (65B52b)	~0.08 abs (65B52b)	γ (65B52b)		Pt-n-p (65B52b)

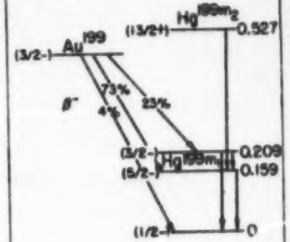
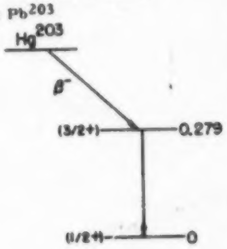
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and schemes	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{77}Ir^{197}$	D chem, excit (25C52, 65B52b)		β^- (65B52b)	7 m (25C52, 65B52b)	1.65, 0.6 abs (65B52b)	γ (65B52b)		Pt-γ-p (25C52); Pt-n-pn (65B52b)
Ir^{198}	E excit (65B52b)		β^- (65B52b)	45 s (65B52b)	3.6 abs (65B52b)	0.78 scint spect (65B52b)		Pt-n-p (65B52b)
$_{78}Pt^{190}$		0.012 (28L49a)						
Pt^{191}	B chem, excit (2W48a, 90M52)		EC (2W48a)	3.00 d (2W49c, 90M52)		0.083, 0.096, 0.173 spect (116S52a); 0.6, 1.5 abs, abs conv (2W49c)		Ir-d-2n (2W48a, 2W49c); Pt-n-2n (2W48a, 2W49c); daughter Au^{191} (2W48a, 2W49c, 90M52)
Pt^{192}		0.78 (3I47g)						
Pt^{193m}	B chem, excit (2W48a, 90M52)		IT (116S52a); EC (2W48a)	4.33 d (2W49c) 4.6 d (90M52)		0.135 (K/L 0.28, $L_I/L_{II}/L_{III}$ 1/0/2) spect conv (116S52a); 0.2, 1.5 abs (2W49c)		Ir-d-2n (2W49c); Pt-n-γ, Pt-n-2n, Pt-d-p (2W49c); Pt-γ-n (116S52a); daughter Au^{193} (2W49c, 90M52)
Pt^{194}		32.8 (3I47g)					Pt^{194}, I = 0 (87M50)	
Pt^{195m}	B chem (12M37); chem, genet (104S52)		IT (104S52)	3.5 d (15H48a); 3.6 d (104S52); 4.4 d (79H52); 3.3 d (12M37)		0.029 (e/γ >7.5), 0.097 (e/γ 9.0, K/L 5.7), 0.126, 0.129 (e/γ very large, K/L 0.26) spect, spect conv, γ-conv coinc (104S52); 0.099, 0.130 (K/L 0.1) spect conv (10C52a); 0.126 (K/L 0.23) spect conv (15H48a)	 Pt^{195m} (13/2+) 0.255 Au^{195} (3/2+) EC (5/2-) 0.126 (3/2-) 0.097 (1/2-) 0 (104S52)	Pt-n-γ (26M48e, 79H52, 104S52, 12M37, 1P37, 2S47, 34H51); Pt-d-p (9K41b); Pt-γ-n (25C52); daughter Au^{195} (180 d) (104S52)
Pt^{195}		33.7 (3I47g)					Pt^{195}, I = 1/2 (87M50)	
Pt^{196}		25.4 (3I47g)					Pt^{196}, I = 0 (87M50)	
Pt^{197m}	B chem (28S41); chem, excit, cross bomb (25C52)		IT (15H48a)	78 m (15H48a); 80 m (28S41); 88 m (25C52)		0.337 (e/γ very large, K/L 1.3) spect conv (15H48a)		Pt-d-p (28S41); Pt-n-2n (28S41); Pt-γ-n (60M48, 25C52); Hg-n-α (28S41); Au-n-p (?) (2W50f)
Pt^{197}	A chem (10C36); chem, excit (12M37)		β^- (12M37)	18 h (12M37); 17.4 h (10C52a)	0.670 spect (105S52, 34H51); 0.7 abs (9K41b, 28S41)	0.077, 0.191 (K/L 6.0) spect conv (10C52a); 0.077, 0.191 spect, spect conv (105S52); others (4B49)	see Au^{197m}, Hg^{197} Q_{β}^{-} 0.75 (105S52)  Pt^{197} (1/2-) β^- 0.268 0.077 (3/2+) 0 (105S52)	Pt-n-γ (12M37, 28S41, 2S47, 79H52); Pt-d-p (10C36, 9K41b, 28S41, 9K42, 2W48a); Pt-γ-n (29C52, 25W48); Pt-n-2n (28S41); Hg-n-α (28S41)

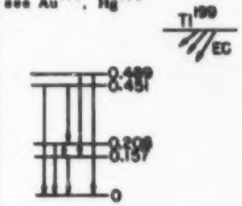
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{78}Pt^{198}$		7.23 (3I47g)						
Pt^{199}	A n-capt (77M35b, 12A35); chem, n-capt, excit (28S41)		β^- (12M37)	31 m (12M37)	1.8 abs (9K41b, 28S41)			Pt-n-γ (12A35, 77M35b, 12M37, 28S41, 2S47, 50H51); Pt-d-p (28S41, 9K41b, 10C36); Hg-n-α (28S41)
Pt	F n-capt (10C50g)		β^- (10C50g)	82 d (10C50g)	0.5 abs (10C50g)	0.6 abs (10C50g)		Pt-n-γ (10C50g)
$_{79}Au^{183-187}$	D chem, excit (3T49)		EC, β^+, α -0.01% (3T49)	4.3 m (42R52)	α: 5.07 ion ch (42R52)			spall Pt (42R52), Au (3T49, 42R52)
Au^{191}	B chem, genet (2W49c, 90M52)		EC (2W49c)	18 h (90M52); -1 d (2W49c)		0.053, 0.064, 0.111, 0.123, 0.166, 0.250, 0.405 spect conv (90M52)		Ir-α-4n (2W49c); Pt-d-3n (2W49c); parent Pt^{191} (2W48a, 2W49c, 90M52); daughter Hg^{191} (90M52)
Au^{192}	B chem, excit (2W49c); chem, genet (42T52, 33F52)		EC, β^+ (2W49c)	5.0 h (42T52); 4.7 h (2W49c); 4.1 h (33F52)	β^+: -1.9 abs (2W49c); conv: -0.4 abs (2W49c)	2-3 abs (2W49c)		Ir-α-3n (2W49c); Pt-d-2n (2W49c); daughter Hg^{192} (33F52, 42T52)
Au^{193}	B chem, genet (2W49c, 90M52)		EC (2W49c)	15.8 h (2W49c, 90M52); 15.3 h (33F52)		0.051, 0.060, 0.084, 0.093, 0.109, 0.165, 0.177, 0.235 spect conv (90M52)		Ir-α-2n (2W49c); Pt-d-n, Pt-d-3n (2W49c); parent Pt^{193} (2W49c, 90M52); daughter Hg^{193} (33F52, 90M52)
Au^{194}	B chem, excit (2W49c)		EC -97%, β^+ -3% (2W49c)	39.5 h (2W49c); 39 h (82S49)	1.8 abs (2W49c)	0.291 (e/γ 0.054, K/L 2), 0.328 (e/γ 0.19, K/L 2), 0.466 (weak), 1.48 (e/γ 0.0026), 2.1 spect, spect conv (82S49)		Ir-α-3n (2W49c); Pt-d-2n, Pt-d-3n (2W49c); Pt-p-n (82S49)
Au^{195m}	B chem, genet (34H52a)		IT (34H52a)	0.5 m (34H52a)		0.056, 0.259 spect conv (34H52a)		daughter Hg^{195m} (34H52a)
Au^{195}	B chem, excit (2W49c); chem, genet (30D52)		EC (2W49c)	180 d (82S49, 30D52); 185 d (2W49c)		0.0308, 0.0990, 0.130 spect conv (30D52); 0.029 (L/M 4.6), 0.097 (K/L 5.8), 0.126 spect, spect conv, γ-conv coinc (104S52); others (34H51, 82S49)	see Pt^{195m}	Ir-α-2n (2W49c); Pt-d-n, Pt-d-2n, Pt-d-3n (2W49c); Pt-p-n (82S49); daughter Hg^{195m} (30D52)

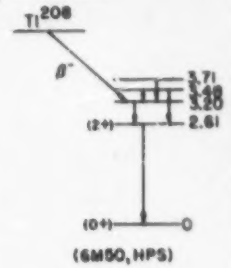
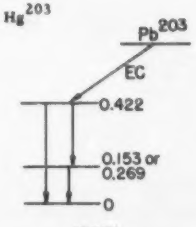
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{79}Au^{196}$	B chem, excit (12M37)		EC or IT (2W49c)	14. 0 h (2W49c); 13 h (12M37)				Au-n-2n (12M37, 2W49c); spall U (?) (6F51)
Au^{196}	A chem, excit (12M37)		EC ~95%, β^- ~5% (82S49); EC ~80%, β^- ~20% (2W49c)	5. 55 d (2W49c); 5. 60 d (82S49)	β^-: 0. 27 spect (106S52); 0. 30 spect (82S49); 0. 3[illegible] abs (2W49c)	with EC: 0. 332, 0. 354 spect conv (106S52); 0. 330 (K/L 1. 7), 0. 358 (K/L 1. 7) spect conv (82S49); with β^-: 0. 426 (e_L/γ 0. 007, L/M+N 3. 5), no 0. 175 γ spect conv, β-conv coinc (106S52); 0. 175 spect conv (82S49)	 Au^196 EC β⁻ 0.426 (2) 0.686 0.354 0.332 (0+) 0 (0+) 0 (106S52, 82S52, HPS)	Pt-d-n (9K41b, 2W49c, 106S52); Pt-p-n (82S49); Au-n-2n (12M37, 2W49c); Au-γ-n (25W48); spall U (?) (6F51)
Au^{197m}	A excit (37W45a)		IT (37W45a)	7. 4 s (40F47); 7. 5 s (37W45a)		0. 130 (e_K/γ <2. 0, K/L/M = 1/7. 5/3. 6), 0. 279 (e_K/γ ~0. 3) spect conv (63M52c); 0. 273 spect conv, conv-conv coinc (34H48a); 0. 275 scint spect (24C52); 0. 25 abs conv (37W45a)	 Au^197m (11/2-) 0.409 (5/2+) 0.279 (3/2+) 0 (63M52c, HPS)	Au-γ-γ (37W45a); Au-n-n (37W45a, 40F47); daughter 25 h Hg^{197} (40F47)
Au^{197}		100 (1D35a)					Au^{197}, I = 3/2 (87M50)	
Au^{198}	A chem, n-capt (12A35, 12M37)		β^- (12M37); no EC (lim 0. 2%) (38M52); no EC (lim 0. 4%) (25R49); no β^+ (lim 0. 003%) (41M51)	2. 69 d (57S49, 9S49b); 2. 73 d (38S51, 33D46); 2. 66 d (69C51)	β_1 0. 963 spect (average of 9S48, 2L49a, 10L49, 82S49, 107S49, 4E51); β_2 0. 290 (coinc with 0. 680 γ) β-γ coinc spect (48B51a); β_3 1. 37 (0. 01%) spect (4E51)	γ_1 0. 41177 cryst spect (100M52, 34D48); γ_1 0. 4116 spect (29L51); γ_1 (e_K/γ 0. 031, K/L 3. 1, L/M 3. 3) spect conv (50S52); γ_1 (e_K/γ 0. 03, K/L 3, L/M 3. 3) spect, spect conv (7S49e); γ_1 (e_K/γ 0. 029, K/L 2. 1, L/M 4. 3) spect conv (82S49); γ_1 (e_K/γ 0.026 K/L 2. 2, L/M 4) spect conv (107S49); γ_1 (e_K/γ 0. 03, K/L+M 2. 3) spect conv (29F52); γ_1 (L_{II}/L_{III} 2. 5) spect conv (63M52a); γ_2 0. 676 (0. 5%, e_K/γ 0. 034, K/L 5. 7), γ_3 1. 088 (0. 1%, e_K/γ 0. 005, K/L 6. 3) spect, spect conv (4E51, 4E51a, 6W52); γ_2 0. 680 (1%, coinc with 0. 411 γ and 0. 29 β^-), γ_3 1. 09 (~0. 2%) scint spect, β-γ coinc (48B51a); γ_2 0. 673 (1. 4%), γ_3 1. 08 (0. 3%) spect (57H51b); γ_2 0. 67 (1. 4%, coinc with 0. 411 γ), γ_3 1. 09 (0. 3%) scint spect, γ-γ coinc (69C51a, 69C51); others (18P50a, 2L48, 2L49a, 9S49b, 31A50a, 12H50, 38T49, 4F44, 72C42, 7S47g, 15J48, 25R48, 52M51)	Q_β^- 1. 374 (HPS)  Au^198 (3-) β⁻ ~99% ~1% ~0.01% (2+) 1.09 (2+) 0.411 (0+) 0 (HPS)	Au-n-γ (12A35, 12M37, 1P37, 16D41, 2S47, 50H51); Au-d-p (9K41c); Hg-n-p (28S41); Pt-p-n (82S49, 82S48); spall U (6O48)

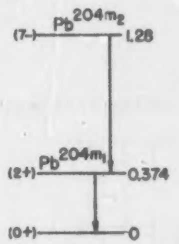
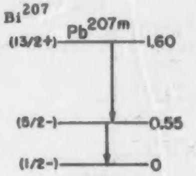
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{79}Au^{199}$	A chem, genet (12M37)		β^- (9K41b)	3.15 d (8B52b); 3.2 d (104S52); 3.3 d (12M37)	0.460, 0.297 (coinc with 0.158 γ), 0.250 (coinc with 0.207 γ) β-γ spect coinc (8B52a); ~0.47 β^- (not coinc with γ) β-γ coinc (11S53) 0.47 (~4%), 0.30, 0.25 spect (108S51); 0.443 (~7%), 0.291 spect (104S52); 0.32 spect (86B49a); abs (37M49); others (26M48e, 9K41b)	γ_1 0.050 (e_L/γ 6), γ_2 0.159 (e_K/γ 0.19, K/L 0.6), γ_3 0.209 (e_K/γ 0.54, K/L 5.4) ($\gamma_1/\gamma_2/\gamma_3$ = 0.84/100/23.8; spect, spect conv, γ-γ coinc (108S51); γ_1 (coinc with γ_2), γ_3 (not coinc with γ_1 or γ_2) scint spect, γ-γ coinc (11S53); 0.050, 0.158 (e_K/γ 0.24, K/L 0.73, L/M 3.3), 0.208 (e_K/γ 0.62, K/L ~5.6, L/M ~4) spect, spect conv, scint spect, γ-γ, β-γ coinc (7S51); 0.0498, 0.159 (K/L 0.56, L/M 3.6), 0.208 (K/L 4.5) spect conv (10C52a); others (104S52, 86B49a, 37M49, 26M48e, 67H50, 67H50a, 63M52a, 4B49, 34H51, 10C50g)	see Tl^{199}, Hg^{199} Q_β^- 0.46 (HPS)  Au199 Hg199m2 Hg199m1 (3/2-) (13/2+) (3/2-) (5/2-) (1/2-) β- 4% 73% 23% 0.527 0.209 0.159 0 (108S51, 104S52, 18G52)	Pt-d-n (9K41b); Au-n-γ (second order reaction) (67H50a); Hg-n-p (28S41); daughter Pt^{199} (12M37, 86B49a, 37M49, 67H50); parent Hg^{199m_1} (14G51a, 8B52a)
Au^{200}	B chem (28S41); chem, sep isotopes, excit (65B52a)		β^- (28S41)	48 m (65B52a, 28S41)	2.2 abs (65B52a); ~2.5 abs (28S41)	1.13, 0.39 scint spect (65B52a)		Hg-n-p (28S41, 3M42); Hg^{201}-γ-p (65B52a); Tl-n-α (3M42)
Au^{201}	B chem, excit, sep isotopes (65B50, 65B52a)		β^- (65B52a)	26 m (65B52a)	1.5 abs (65B52a)	0.55 scint spect (65B52a)		Hg-γ-p (65B50); Hg^{202}-γ-p (65B52a)
Au^{202,204}	E excit (65B52a)		β^- or IT (65B52a)	25 s (65B52a)				Hg-n-p (65B52a)
Au^{203}	B chem, excit, sep isotopes (65B52a)		β^- (65B52a)	55 s (65B52a)	1.9 abs (65B52a)	0.69 scint spect (65B52a)		Hg-n-pn (65B52a); Hg^{204}-γ-p (65B52a)
$_{80}Hg^{<195}$	E chem (3T49)		α (3T49)	0.7 m (42R52)	α: 5.60 ion ch (42R52)			spall Au (3T49)
Hg^{189}	D chem, excit (42T52)			30 m (42T52)				spall Au (42T52)
Hg^{190}	D chem, excit (42T52)			99 m (42T52)				spall Au (42T52)
Hg^{191}	D chem, excit (90M52)		EC (90M52)	12.4 h (90M52)				spall Au, parent Au^{191} (90M52)
Hg^{192}	D chem, excit (33F52, 90M52)		EC (90M52); β^+ (33F52)	5.7 h (33F52); 8.4 h (90M52)	1.18 spect (33F52)	1.4 abs (33F52)		spall Au (90M52, 33F52); parent Au^{192} (33F52, 42T52)
Hg^{193}	B chem, excit (33F52, 90M52)		EC (33F52)	10.0 h (33F52); 14.5 h (?), 29.0 h (?) (90M52)				Au-p-5n (33F52, 90M52); parent Au^{193} (33F52, 90M52)

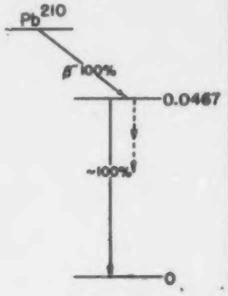
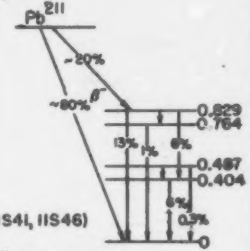
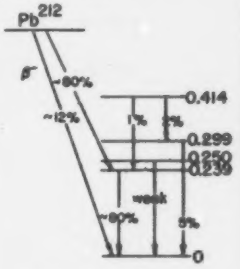
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{80}Hg^{195m}$	B chem, excit (30D52, 33F52)		EC, IT (30D52)	38 h (30D52); ~31 h (33F52); 40 h (34H52a)		0.036, 0.056 (coinc with Au^{195m}), 0.122, 0.259 (coinc with Au^{195m}) spect conv (34H52a); 0.037, 0.056, 0.122 (conv in Hg), 0.206, 0.261, 0.318, 0.558 spect conv (30D52)		Au-d-4n (34H52a); Au-p-3n (30D52, 33F52); parent Au^{195} (30D52); parent Au^{195m} (34H52a)
Hg^{195}	B chem, excit (30D52)		EC (30D52)	9.5 h (30D52, 34H52a)		0.061, 0.179, 0.600, 0.780 spect conv (90M52); 0.061, 0.179 spect conv (34H52a)		Au-p-3n (30D52)
Hg^{196}		0.146 (6N50a)						
Hg^{197m_2}	A n-capt (17A36a); chem (12M37); chem, excit, cross bomb (16W41, 23F43)		IT 97%, EC 3% (104S52)	23 h (23F43, 34H51); 25 h (12M37)		with IT: 0.133 (e_K/γ 0.5, K/L/M+N = 1.0/2.4/0.8), 0.164 (e_K/γ 4.6, K/L/M+N = 1.0/2.3/1.2) spect conv, γ-γ coinc (40F50, 34H51); 0.134 (K/L <0.1), 0.165 (K/L ~0.25) spect conv (10C52b); 0.134 ($L_I/L_{II}/L_{III}$ = 0.05/1.1/1.0), 0.165 ($L_I/L_{II}/L_{III}$ = 1.0/<0.1/1.5) spect conv (63M52c); with EC: 0.191 (e_K/γ ~1.7, K/L ~6), 0.275 (weak, e_K/γ ~0.5, K/L ~5) spect conv, γ-γ coinc (40F50, 34H51); others (2H42a, 6V41b, 34H48a, 40F47, 40F50a)	see Au^{197m}  Hg^{197m_2} (13/2+) 0.297 EC Hg^{197m_1} (5/2-) 0.133 Au^{197m} (11/2-) 0.409 Hg^{197} (1/2-) 0 ~1% EC ~99% (5/2+) 0.279 (3/2, 1/2+) 0.268 (3/2+) 0.077 (3/2+) 0 (63M52c, 104S52, HPS)	Pt-α-n (28S41); Au-d-2n (16W41, 9K41c, 23F43); Hg-n-2n (12M37, 23F43, 16W41); Hg-n-γ (17A36a, 16W41, 23F43); Hg-d-p (9K40); parent (3%) Au^{197m} (40F50, 104S52); parent Hg^{197m_1} (20D50, 52M50c)
Hg^{197m_1}	A genet (52M50c, 20D50)		IT (52M50c, 20D50)	7.0×10^{-9} s delay coinc (52M50c); 8×10^{-9} s delay coinc (20D50)		0.13 scint spect (20D50)		daughter Hg^{197m_2} (20D50, 52M50c)
Hg^{197}	A chem, excit, cross bomb (16W41, 23F43)		EC (23F43)	65 h (34H51); 66 h (10C52b); 64 h (23F43)		0.077 (e_L/γ 2.5, L/M 3.6), 0.191 (e_K/γ ~1.7, K/L ~6) spect conv, γ-γ coinc (34H51, 40F50); 0.077 ($L_I/L_{II}/L_{III}$ = 1.0/0.45/0.34) spect conv (63M52c); 0.078 (L_I/M 4), 0.191 (K/L ~9) spect conv (10C52b); 0.077, 0.278 spect conv (30D52); others (2H42a, 40F47, 34H48a)		Au-d-2n (23F43, 16W41); Hg-n-2n (23F43, 16W41); Hg-n-γ (23F43, 16W41)
Hg^{198}		10.02 (6N50a)					Hg^{198}, I = 0 (87M50)	

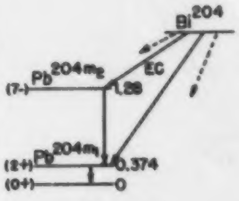
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{80}Hg^{199m_2}$	A chem, excit (6H37, 12M37); mass spect (67B49b)		IT (23F43)	44 m (15H47a, 60M48); 43 m (12M37, 6H37)		0.155 (e/γ 0.25, K/L <0.4), 0.368 (e/γ >11, K/L 1.6) spect conv (15H48a); 0.159 (L_{II}/L_{III} 1.6) spect conv (63M52a); 0.16 γ (coinc with 0.37 γ) scint spect, γ-γ coinc (11S3); others (15H47a, 37M49)	see Au^{199}, Tl^{199}  Hg^{199m_2} (13/2+) 0.527 Au^{199} (3/2-) β⁻ 73% 4% 23% (3/2-) Hg^{199m_1} (5/2-) 0.209 0.159 (1/2-) 0 (108S51, 104S52, 18G52)	Pt-a-n (28S41); Hg-n-2n (12M37, 1P37, 6H37, 67B49b); Hg-n-n (23F43, 16W41, 67B49b); Hg-d-p (9K40); Hg-γ-n (60M48, 37W45a); Hg-γ-γ (16W41)
Hg^{199m_1}	A genet (14G51a)		IT (14G51a)	2.4 x 10^{-9} s delay coinc (8B52a)		0.158 spect conv, β-γ coinc (14G51a, 8B52a)		daughter Au^{199} (14G51a, 8B52a)
Hg^{199}		16.84 (6N50a)					Hg^{199}, I = 1/2 (87M50)	
Hg^{200}		23.13 (6N50a)					Hg^{200}, I = 0 (87M50)	
Hg^{201}		13.22 (6N50a)					Hg^{201}, I = 3/2 (87M50)	
Hg^{202}		29.80 (6N50a)					Hg^{202}, I = 0 (87M50)	
Hg^{203}	A excit (9K40); chem, excit, n-capt (16W41, 23F43); mass spect (5S49a, 67B49a)		β⁻ (23F43)	47.9 d (10C52b); 45.9 d (33W51a); 46.5 d (35L51a); 43.5 d (9S48b)	0.208 β-γ coinc spect (5S49, 5S49a); 0.210 spect (33W51a); 0.205 spect (9S48b); others (37W47)	0.279 (e/γ 0.27, K/L 3) spect, spect conv, β-γ coinc (5S49, 5S49a, 12H50); 0.278 (e_K/γ 0.19, K/L+M 3.7) spect, spect conv (33W51a); ~0.28 (e_K/γ 0.23) scint spect (80H52); 0.279 (K/L ~10) spect conv (10C52b); 0.266 (e/γ 0.3, K/L 3) spect conv (9S48b); others (43M46, 11B50, 4B49, 100B50, 20D50, 52M51)	Q_{β}^{-} 0.487 (5S49, 5S49a) see Pb^{203}  (5S49, HPS)	Hg-n-γ (23F43, 16W41, 3147h, 2S47); Hg-n-2n (16W41, 28S41, 23F43); Hg-d-p (9K40); Hg^{202}-n-γ (35L51a); Tl-n-p (3M42)
Hg^{204}		6.85 (6N50a)					Hg^{204}, I = 0 (87M50)	
Hg^{205}	A n-capt, excit (9K40, 9K42); sep isotopes, n-capt (35L51a)		β⁻ (9K40)	5.5 m (3M42, 9K40); 5.6 m (35L51a)	1.8 abs (35L51a); 1.6 abs (9K40)			Hg-d-p (9K40, 9K42); Hg-n-γ (23F43, 16W41, 2S47); Hg^{204}-n-γ (35L51a); Tl-n-p (3M42); Pb-n-a (3M42)

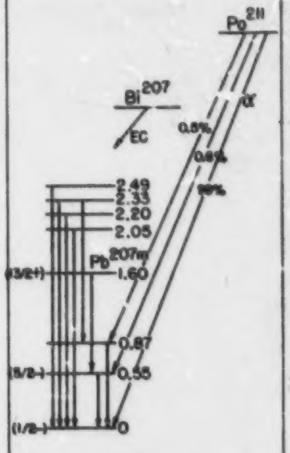
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
81 ^{198}	B chem, excit (7O49)		EC (7O49)	1.8 h (7O49)	conv: ~0.4 abs (7O49)	several γ's, abs (7O49)		Au-α-3n (7O49); daughter Pb^{198} (4N50)
Tl^{199}	A chem (9K40); chem, excit (7O49); genet (energy levels Hg^{199}) (1I53)		EC (7O49); no β^+ (1I51)	7 h (7O49)		0.049, 0.078, 0.103, 0.157, 0.206, 0.246, 0.332, 0.454, 0.490 spect conv, γ-γ coinc (1I51, 1I53)	see Au^{199}, Hg^{199}  (1I53)	Au-α-2n (7O49, 1I51); Hg-d-2n (9K40); daughter Pb^{199} (4N50)
Tl^{200}	A chem, excit (7O49)		EC (7O49); no β^+ (1I51)	27 h (7O49)		0.365, 0.577, 0.622, 0.829, 1.210, 1.360 spect conv (1I51); ~0.4, 1.6 abs (4N50)		Au-α-n (7O49, 1I51); Hg-d-2n (9K40); daughter Pb^{200} (4N50)
Tl^{201}	B chem, excit, cross bomb (4N50)		EC (4N50)	72 h (4N50)		0.210 spect conv, abs (4N50)		Au-α-γ (112S51); Hg-d-2n (9K40); daughter Pb^{201} (4N50)
Tl^{202}	A chem, excit (9K40, 5F41)		EC (9K40, 3M42); EC (L/K ~1), no β^+ or β^- (2W50)	12.5 d (80M52); 11.5 d (2W50); 11.8 d (5F41)		0.435 spect conv, abs (2W50); 0.431 scint spect (80M52)		Hg-d-2n (9K40, 2W50); Tl-n-2n (9K40, 5F41, 3M42, 80M52)
Tl^{203}		29.50 (1B50)					Tl^{203}, I = 1/2 (87M50)	
Tl^{204}	B chem, n-capt (5F40)		β^- ~98%, EC ~2% (33L52); β^- ~98.5%, EC ~1.5% (38M52)	3.5 y (5F41); 2.7 y (3V45)	0.765 spect (33L52); 0.760 scint spect (38M52); 0.783 spect (9S49); 0.77 spect (6P47); others (4H47a, 5F41, 6E50)	no γ (lim 0.01%) (38M52a); no γ (lim 0.5%) (6E50); no γ (5F41); Hg K-x (33L52, 14M52a)	Q_{β}^{-} 0.77 (13S53)	Tl-n-γ (5F40, 2S47); Tl-γ-n (7H49); Tl-d-p (9K40, 5F41)
Tl^{205}		70.50 (1B50)					Tl^{205}, I = 1/2 (87M50)	
Tl^{206}	A n-capt (4P35); chem, genet (7B47); excit, sep isotopes (4N50a)		β^- (5F40, 9K42)	4.19 m (3S52); 4.23 m (5F40); 4.3 m (13A51)	1.51 spect (13A51); 1.65 abs (5F41); 1.8 abs (9K40); no conv (13A51)	no γ (5F40, 7B47, 13A51)	Q_{β}^{-} 1.51 (13A51)	Tl-n-γ (4P35, 1P37, 6H37); Tl^{205}-n-γ (4N50a); Tl-d-p (5F40, 9K40); daughter Bi^{210} (RaE) (7B47); daughter (long-lived) Bi^{210} (4N50a)
Tl^{207} (AcC'')	A chem, genet (1C31)		β^-	4.79 m (3S52); 4.77 m (5F40); 4.76 m (1C31, 3S39)	1.44 abs (6E50); 1.47 abs (3S39a); 1.6 abs (6L38)	0.870 (~0.5%) (11S41)	Q_{β}^{-} 1.44 (13S53)	Pb-n-p (6B40); Pb-γ-p (10B46); natural source, daughter Bi^{211} (AcC)

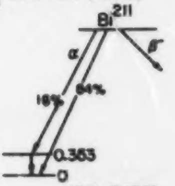
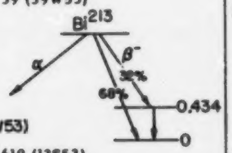
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{81}$Tl^{208} (ThC")	A chem, genet (1C31)		β^-	3.1 m (1C31)	1.792 spect (6M48); 1.795 spect (14H34); 1.805 spect, β-γ coinc (4F48); 1.72 spect (7S47); 1.82 abs (3S33); β^- >1.792 (?) (<1%) spect (6M48)	2.62 (~100%, e/γ ~0.002), 0.859 (~15%, e/γ ~0.02), 0.582 (~80%, e/γ ~0.02), 0.510 (~25%, e/γ ~0.08), 0.277 (~10%, e/γ ~0.3) spect, spect conv (6M50); 2.6143 spect (49L52); 0.51085 spect (49L51); 2.6147 spect conv (110B51); 2.616, 0.510 spect (12H51); 2.615 spect (6W50); 2.58 (100%), 0.575 (100%), 0.51 (50%) spect (2J47); 2.62, 0.582, 0.510, 0.277 spect conv (8E32); 2.62, 0.868, 0.581, 0.502 spect (8B48); 2.62 scint spect (11B50); no 3.2 γ (8B48, 9B50)	Q_β^- 4.99 (13S53)  Tl^{208} β^- 3.71 3.48 3.20 2.61 (2+) (0+) 0 (6M50, HPS)	natural source, daughter Bi^{212} (ThC)
Tl^{209}	A chem, genet (4H50)		β^- (4H50)	2.2 m (4H50)	1.99 spect (39W53); 1.8 abs (4H50)	0.12 scint spect (39W53)	Q_β^- 3.92 calc (13S53)	daughter Bi^{213}, parent Pb^{209} (4H47, 11E47)
Tl^{210} (RaC")	A chem, genet (1C31)		β^-	1.32 m (1C31); 1.5 m (9B50); ~1.3 m (8D37)	1.8 cl ch (6L38); 2.0 abs (2D37)	no γ >2.8, D-γ-p reaction (9B50)	Q_β^- 5.39 calc (13S53)	natural source, daughter Bi^{214} (RaC), parent Pb^{210} (RaD)
$_{82}$Pb^{198}	B chem, genet (7K51)		EC (7K51)	25 m (7K51)				Tl-p-6n (7K51); parent Tl^{198} (7K51, 4N50); daughter Bi^{198} (4N50)
Pb^{199}	B chem, genet (4N50)		EC (4N50)	~80 m (4N50)				daughter Bi^{199}, parent Tl^{199} (4N50)
Pb^{200}	A chem, genet (4N50)		EC (4N50)	18 h (4N50)		0.139, 0.320 spect conv (8O51)		daughter Bi^{200}, parent Tl^{200} (4N50)
Pb^{201m}	D chem, excit (89H52)		IT (89H52)	50 s (89H52)		0.25, 0.42, 0.67 scint spect (89H52)		Tl-p-3n (89H52)
Pb^{201}	B chem (5H46); chem, genet (4N50)		EC (4N50)	8 h (4N50)				Tl-d-4n (5H46); daughter Bi^{201}, parent Tl^{201} (4N50)
Pb^{202m}	E excit (89H52)		IT (89H52)	5.6 s (89H52)		0.89 scint spect (89H52)		Tl-p-2n (89H52)
Pb^{202}		<4 x 10^{-4} (9D49)		>500 y genet, yield (2T47, 4N50)				Tl-d (2T47)
Pb^{203}	B chem, excit (3M42); chem, excit, cross bomb (2T47)		EC (3M42, 8O51)	52 h (5F40, 2T47); 54 h (9K40, 12D42)		0.153, 0.269, 0.422 spect conv (8O51); 0.270, 0.420 abs conv (3M42); 0.270, ~0.470 spect, spect conv (9L44)	see Hg^{203}  (8O51)	Tl-d-2n (5F40, 9K40, 5F41, 2T47); Tl-p-n (12D42); Pb-n-2n (3M42); Pb^{204}-n-2n (2T47); Pb-γ-n (10B46)

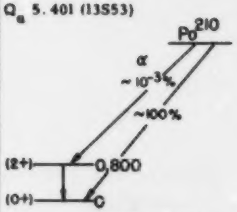
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{82}Pb^{204m_2}$	B chem (5F41); chem, excit, genet (2T47, 7K51)		IT (3M42)	68 m (3M42); 65 m (5F41)		0.905 (e/γ ~0.1, K/L 1.5), 0.374 (with Pb^{204m_1}, e/γ ~0.05, K/L 2.1) spect conv, abs conv, abs (14S50); 0.90 abs conv (3M42); 1.1 abs conv, abs (5F41)	see Bi^{204}  Pb^{204m_2} (7-) 1.28 Pb^{204m_1} (2+) 0.374 (0+) 0 (16G52)	Tl-d-n (5F41); Tl-d-3n (2T47); Pb-n-n (7D39, 3M42); Pb-γ-2n (10B46); daughter Bi^{204} (2T47, 14S50, 7K51), ~4% (2T47); parent Pb^{204m_1} (14S50)
Pb^{204m_1}	B genet (14S50)		IT (14S50)	3×10^{-7} s delay coinc (14S50)		0.374 (see γ's of Pb^{204m_2})		daughter Pb^{204m_2} (14S50); daughter Bi^{204} (14S52b)
Pb^{204}		1.48 (6N38)					Pb^{204}, I = 0 (87M50)	
Pb^{206}		23.6 (6N38)					Pb^{206}, I = 0 (87M50)	
Pb^{207m}	A excit, sep isotopes (24C51); chem, genet (23F52c)		IT (24C50)	0.84 s (24C52); 0.82 s (51L51); 0.80 s (89H52)		0.55, 1.05 scint spect (24C51); 0.5, 1.1 scint spect (23F52c)	see Bi^{207}  Pb^{207m} (13/2+) 1.60 (5/2-) 0.55 (1/2-) 0 (16G52)	Pb^{207}-n-n (24C51); Pb-n-n (51L51); daughter Bi^{207} (23F52c); not daughter Po^{211} (lim 0.005%) (23F52a)
Pb^{207}		22.6 (6N38)					Pb^{207}, I = 1/2 (87M50)	
Pb^{208}		52.3 (6N38)					Pb^{208}, I = 0 (87M50)	
Pb^{209}	A chem (6T37, 9K40); chem, sep isotopes (5F41a)		β^- (9K40, 5F41)	3.22 h (5F41); 2.75 h (9K40)	0.635 spect (47W52a); 0.620 spect (39W53); 0.68 spect (11R47); others (9K40, 5F41, 19L44)	no γ, no conv (4W44, 47W52a); no γ (19L44, 39W53)	Q_β^- 0.64 (13S53)	Pb-d-p (6T37, 9K40, 5F41, 5F41a, 9K42, 3H50); Pb-n-γ (3M42); Bi-d-2p (112S51); Bi-n-p (3M42); daughter Po^{213} (4H47, 11E47, 11M49); daughter Tl^{209} (11E47, 4H47)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{82}Pb^{210}$ (RaD)	A chem, genet (1C31)		β^-	22 y (1C31)	0.018 ion ch (5I52); 0.018 scint spect, β-γ coinc (87B52a); 0.017 (≤90%), 0.056 (≥10%) ion ch (33J52); others (8L39, 12S46)	γ_1 0.0465, no other γ between 0.016 and 0.060 (lim ~2% of γ_1) cryst spect (26E52); γ_1 0.0467, no other γ (lim 5% of γ_1) cryst spect (88B52a); 0.0467 (3.5%) spect conv, abs (24B30, 8S31, 19G32, 6D33); γ_1 (e_L/γ ~16, $L_I/L_{II}/L_{III}/M$ = 1.0/0.09/0.019/0.29) spect conv (6C50); γ_1 (e/γ ~23) spect conv (33L51); γ_1 (e/γ ~17, using γ = 3.5%) spect conv (14B51); 0.032, 0.037, 0.0467 cryst spect (8F62); 0.065 (<0.2%), 0.0467 (2.8%), 0.043 (0.2%), 0.037 (0.2%), 0.032 (0.4%), 0.023 (~1%), 0.007 (~10%) cryst spect, cl ch, abs (9T46); others (9T43, 10C51, 4T52a, 63C52, 35C52)	Q_β^- 0.065 (5I52)  (26E52, HPS)	natural source, daughter Tl^{210} (RaC"), daughter Po^{214} (RaC'), parent Bi^{210} (RaE)
Pb^{211} (AcB)	A chem, genet (1C31)		β^-	36.1 m (3S39); 36.0 m (1C31)	1.39 (~80%), ~0.5 (~20%) abs (3S39a)	0.065, 0.083, 0.404, 0.425, 0.487, 0.764, 0.829 spect, spect conv, abs (11S42); 0.829 (5%) (54M44); 0.8 abs (3S39a)	Q_β^- 1.4 (13S53)  Pb211 ~20% ~80% β⁻ 0.829 0.764 13% 1% 6% 0.487 0.404 6% 0.3% 0 (11S41, 11S46)	natural source, daughter Po^{215} (AcA), parent Bi^{211} (AcC)
Pb^{212} (ThB)	A chem, genet (1C31)		β^-	10.6 h (1C31)	0.355, 0.589 spect, β-γ coinc (4F48); 0.331, 0.569 (~12%) spect (6M48a); 0.340 spect (6G49); 0.36 spect (3S33)	γ_3 0.2386 spect conv (49L51); γ_1 0.115, γ_2 0.176, γ_3 0.238, γ_4 0.249, γ_5 0.299 spect conv (8E32); γ_3 0.238 (~40%), γ_5 0.300 (~4%) spect (6M50); γ_3 (L_I/L_{II} ~18, M_I/M_{II} ~4.3) spect conv (117S52); γ_3 (e/γ ~1), γ_5 (e/γ ~0.3) (calc from 9F39, 6M48a, 6M50); γ_3 0.238 spect (7S44)	Q_β^- 0.58 (13S53)  Pb212 β⁻ ~80% ~12% 0.414 1% 2% 0.299 0.250 0.239 weak ~80% 5% 0 (11S46, 4F48, 6M48a)	natural source, daughter Po^{216} (ThA), parent Bi^{212} (ThC)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{82}$Pb^{214} (RaB)	A chem, genet (1C31)		β^- (3S33, 7R36)	26.8 m (1C31)	0.65 spect (3S33); 0.72 spect (8C41)	γ_1 0.05323, γ_2 0.24192, γ_4 0.29522, γ_5 0.35199 ($\gamma_2/\gamma_4/\gamma_5$ = 0.2/0.55/1.0) cryst spect (100M52); γ_1 0.0528, γ_2 0.2410, γ_3 0.2578, γ_4 0.2942, γ_5 0.3509 spect (7S44); γ_1 (1.6%) crit abs (9T43a); γ_2 (K/L$_I$ ~6.7), γ_4 (K/L$_I$ ~6.7), γ_5 (K/L$_I$ ~5.9) spect conv (59K51); 0.053, 0.241, 0.257, 0.294, 0.350 spect (8E34); 0.053, 0.242, 0.295, 0.351 spect conv (10C51)		natural source, daughter Po^{218} (RaA), parent Bi^{214} (RaC)
$_{83}$Bi$^{<198}$	E (2T48); chem (4N50)		α (2T48)	1.7 m (4N50)	6.2 ion ch (4N50)			spall Pb (2T48, 4N50)
Bi^{198}	B chem (2T48); chem, genet (4N50)		EC 99+%, α 5 x 10^{-2}% (4N50)	7 m genet (4N50)	5.83 ion ch (4N50)			spall Pb (2T48, 4N50); parent Pb^{198} (4N50)
Bi^{199}	B chem (2T48); chem, genet (4N50)		EC 99+%, α 10^{-2}% (4N50)	~25 m genet (4N50)	5.47 ion ch, abs mica (4N50)			spall Pb (4N50, 2T48); parent Pb^{199} (4N50)
Bi^{200}	B chem, genet (4N50)		EC (4N50)	35 m genet (4N50)				spall Pb, parent Pb^{200} (4N50)
Bi^{201}	B chem (2T48); chem, genet (4N50)		EC 99+%, α 3 x 10^{-3}% (4N50)	62 m (4N50)	5.15 ion ch (4N50)			spall Pb (2T48, 4N50); parent Pb^{201} (4N50)
Bi^{201}	B chem, genet (4N50)		EC (4N50)	~2 h genet (4N50)				spall Pb, parent Pb^{201} (4N50)
Bi^{202}	B chem, genet (7K51)		EC (7K51)	95 m (7K51)				daughter Po^{202} (7K51)
Bi^{203}	B chem, genet (4N50)		EC (4N50); α ~10^{-5}% (15D52a)	12 h genet (4N50)	α: 4.85 range emuls (15D52a)			spall Pb, parent Pb^{203} (4N50); daughter Po^{203} (7K51)
Bi^{204}	B chem, sep isotopes, cross bomb (2T47)		EC, no β^+ (2T47)	12 h (2T47)	conv: ~0.2, ~0.8 (weak), abs, spect (2T47)	0.217 spect conv (14S50a)	 Bi^{204} EC (7-) Pb^{204m_2} 1.28 (2+) Pb^{204m_1} 0.374 (0+) 0 (18G52, HPS)	Pb^{204}-d-2n (2T47); Pb-d-2n (14S50); daughter Po^{204} (7K51); Tl-α-3n, parent (~4%) Pb^{204m_2} (2T47); parent Pb^{204m_1} (14S52b)
Bi^{205}	B chem, genet, sep isotopes (7K51)		EC (7K51)	14.5 d (7K51)		0.431, 0.527, 0.550, 0.746, 1.84 spect conv (7K51)		daughter Po^{205} (7K51); daughter At^{209} (12B51)

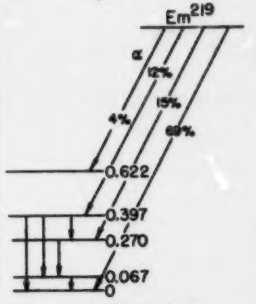
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{83}Bi^{206}$	B chem, sep isotopes (5F41a, 2T47)		EC (9L44); EC, no β^+ (13A51a)	6.4 d (9K40)		0.182, 0.234, 0.260, 0.341, 0.396, 0.470, 0.505, 0.536, 0.590, 0.803, 0.880, 0.889, 1.020, 1.097, 1.720 spect, spect conv, γ-γ coinc (13A51a); others (9K40, 5F4', 2T47a)		Tl-α-3n (2T47); Pb-d-2n (5F41, 5F41a, 9K40, 13A51a); Pb^{207}-d-3n (2T47); Pb^{206}-d-2n (5F41a); daughter Po^{206} (2T47a); daughter At^{210} (4N50b)
Bi^{207}	B chem, genet (4N51)		EC (5G50, 4N51)	~50 y genet (4N51)		0.56, 1.1 (coinc with 0.56 γ) scint spect, γ-γ coinc (7G51a); 0.064 or 0.137, 0.565, 1.063, 1.46, 2.05, 2.20, 2.33, 2.49 spect conv (4N51); with Pb^{207m}: 0.5, 1.1 scint spect (23F52c)	 Po²¹¹ α Bi207 EC 0.5% 0.6% 99% 2.49 2.33 2.20 2.05 Pb207m 1.60 0.87 0.55 0 (3/2+) (5/2-) (1/2-) (18G52, NPS)	Pb-d-3n (4N51); daughter At^{211} (4N51); parent Pb^{207m} (23F52c)
Bi^{208}	F chem (4N51)		EC (4N51)	long (4N51)		no γ (?) (4N51)	Q_α 3.2 calc (13S53)	Pb-d-2n (4N51)
Bi^{209}		100 (6N38b)					Bi^{209}, I = 9/2 (87M50) Q_α 3.2 calc (13S53)	
Bi^{209}	G α's not seen (91H52)		α (7F51)	>>10^{17} y sp act (91H52); 3 x 10^{17} y sp act (7F51)	~3.15 range emulsion (7F51)			
Bi^{210} (RaE)	A chem, genet (1C31)		β^- 99+%, α 5 x 10^{-5}% (7B47)	5.02 d (111B52); 4.85 d (7S47f); 5.0 d (1C31); 5.1 d (15H45a)	β^-: 1.17 spect (10L37, 9F39a, 9N40, 2Z49, 10L49)	no γ (19G36, 6L47, 10C51)	Q_{β}^- 1.17, Q_α 5.06 calc (13S53)	natural source, daughter Pb^{210} (RaD), parent Po^{210} (RaF); parent Tl^{206} (7B47); Pb-d-γ (112S51); Pb-α-pn (2T47); Bi-d-p (12L36, 10C40, 47H40); Bi-n-γ (7M48, 2S47)
Bi^{210}	A chem, genet (4N50a); chem, mass spect (52L52)		α, β^- or IT (~0.3%) (52L52)	~10^6 y yield (52L52)	4.93 ion ch (52L52)		Q_α 5.03 (52L52)	Bi-n-γ, parent Tl^{206} (4N50a); parent Po^{210} (52L52)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{83}Bi^{211}$ (AcC)	A chem, genet (1C31)		α 99.68%, β^- 0.32% (1C31)	2.16 m (1C31)	α: 6.618 (84%), 6.272 (16%) spect (9H38, 1R31); 6.621 (82.6%), 6.274 (17.4%) spect (13V52)	0.350 abs (3S39a); -0.35 (e_K/γ = 0.18, K/L 5.5) (4T52b, 10F52); 0.354 abs (16H25)	Q_α 6.746 (13S53) Q_β^- 0.61 calc (13S53)  Bi^{211} α β^- 16% 84% 0.353 0 (1C31, 9H38)	natural source, daughter Pb^{211} (AcB), parent Po^{211} (AcC'), parent Tl^{207} (AcC")
Bi^{212} (ThC)	A chem, genet (1C31)		β^- 66.3%, α 33.7% (6K38)	60.5 m (1C31)	α: 6.086 (27.2%), 6.047 (69.9%), 5.765 (1.7%), 5.622 (0.15%), 5.603 (1.1%), 5.481 (0.016%) spect (48R51); 6.082 (27%), 6.042 (70%), 5.760 (1.8%), 5.618 (0.2%), 5.599 (1.1%) spect (11L34); β^-: 2.250 spect (6M48a); 2.256 spect, β-γ coinc (4F48); others (7C48, 3S33)	with α: 0.040 (strong), 0.144, 0.164, 0.288, 0.328, 0.432, 0.452, 0.472, other γ's, spect, spect conv (11S37, 11S46); 0.040 (-4%) coinc abs (21K47); ($e/\gamma \geq 14$ calc from 21K47, 9F39, 14B49); 0.295 spect conv (117S52); with β^-: 2.20, 1.81 (-7%), 1.61 (-7%), 1.34 (-5%), 1.03 (-6%), 0.83 (-19%), 0.72 (-19%) spect (2J47) (intensities calc from 2J47); 0.726 (-6%, e/γ 0.015) spect (6M50); others (5L47)	Q_α 6.203, Q_β^- 2.25 (13S53)	natural source, daughter Pb^{212} (ThB), parent Po^{212} (ThC') and Tl^{208} (ThC")
Bi^{213}	A chem, genet (11E47, 4H47)		β^- 98%, α 2% (11E47, 4H50a, 39W53)	47 m (4H47); 46 m (11E47)	β^-: 1.39 (68%), 0.959 (32%) spect (39W53); -1.3 abs (4H47, 11E47); α: 5.86 ion ch (11E47); 6.0 ion ch (4H47)	0.434 spect conv, scint spect (39W53)	Q_α 5.97 (13S53) Q_β^- 1.39 (39W53)  Bi^{213} α β^- 32% 68% 0.434 0 (39W53)	daughter At^{217}, parent Po^{213} (4H47, 11E47, 4H50a); parent Tl^{209} (4H50)
Bi^{214} (RaC)	A chem, genet (1C31)		β^- 99+%, α 0.04% (1C31)	19.7 m (1C31)	α: 5.505 (45%), 5.444 (55%) spect (11L34); 5.52 (37%), 5.47 (46%), 5.33 (17%) spect (7C48a); β^-: 3.17 (-23%), 1.65 (-77%) spect (8C41, 5L47); 3.15 spect, abs (3S33)	with β^-: γ_1 0.6094 cryst spect (100M52); γ_1 0.606 (K/L 5.6), γ_2 0.766, γ_3 0.933, γ_4 1.120 (K/L 6.7), γ_5 1.238 (K/L 5.9), γ_6 1.379, γ_7 1.520, γ_8 1.761 (K/L 6.7), γ_9 1.820, γ_{10} 2.200, γ_{11} 2.420 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7/\gamma_8/\gamma_9/\gamma_{10}/\gamma_{11}$ = 9/1.3/1.1/2.6/1.0/0.9/0.7/3.2/0.2/1.00/0.5) spect, spect conv (59K52, 5M50); 0.426, 0.498, 0.607, 0.766, 0.933, 1.120, 1.238, 1.379, 1.414, 1.761, 2.193 spect conv (8E34); 0.609, 0.769, 0.935, 1.122, 1.241, 1.419, 1.766 spect conv (10C51); with α: 0.0625, 0.191 spect conv (10C51); others (8E30, 8C41)	Q_α 5.610 (13S53) Q_β^- 3.17 (8C41)	natural source, daughter Pb^{214} (RaB), daughter At^{218}, parent Po^{214} (RaC'), parent Tl^{210} (RaC"); descendent Fr^{222} (8H51a)
Bi^{215}	A chem, genet (8H53)		β^- (8H53)	8 m (8H53)			Q_β^- 2.01 est (60G53)	natural source, daughter At^{219}, parent Po^{215} (8H53)

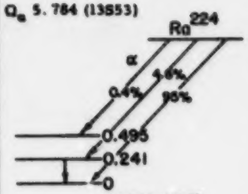
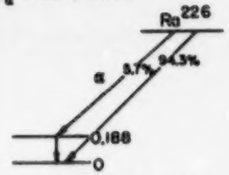
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{84}Po^{200}$	B chem, genet (7K51a)		EC, α (7K51a)	11 m (7K51a)	5.84 ion ch (7K51a)			Bi-p-10n, parent Bi^{200} (7K51a)
Po^{201}	B chem, genet (7K51a)		EC, α (7K51a)	18 m (7K51a)	5.70 ion ch (7K51a)			Bi-p-9n, parent Bi^{201} (7K51a)
Po^{202}	B chem, genet, excit (7K51)		EC, α (7K51)	52 m genet (7K51)	5.59 ion ch (7K51)			Bi-p-8n, Pb-α-spall, parent Bi^{202} (7K51)
Po^{203}	B chem, genet (7K51)		EC (7K51)	47 m genet (7K51)				Bi-p-7n, Pb-α-spall, parent Bi^{203} (7K51)
Po^{204}	B chem, genet (7K51)		EC ~99%, α ~1% (7K51)	3.8 h (7K51)	5.37 ion ch (7K51)			Bi-p-6n, Pb-α-spall, parent Bi^{204}, parent Pb^{200} (7K51)
Po^{205}	B chem, genet, sep isotopes, excit (7K51)		EC 99+%, α 0.074% (17H51a)	1.5 h genet (7K51)	5.2 ion ch (7K51a)			Pb^{204}-α-3n, parent Bi^{205}, parent Pb^{201} (7K51)
Po^{206}	B chem, genet, sep isotopes (2T47a)		EC ~90%, α ~10% (2T47a)	9 d (2T47a)	5.218, 5.064 spect (4R52b); 5.21 ion ch (7K51a)	0.8 abs (2T47a)	Q_α 5.321 (HPS)	Pb^{204}-α-2n, parent Bi^{206} (2T47a)
Po^{207}	B chem, excit, sep isotopes (2T47a)		EC 99+%, α ~10^{-2}% (2T47a)	5.7 h (2T47a)	5.10 ion ch (7K51a)	1.3 abs (2T47a)		Pb^{206}-α-3n (2T47a)
Po^{208}	A chem, excit, sep isotopes (2T47a)		α (2T47a)	2.93 y (2T50)	5.108 spect (4A52b); 5.109 spect (4R52b); 5.19 ion ch (7K51a)	no γ (2T47a, 18H51)	Q_α 5.208, Q_{EC} 1.3 calc (13S53)	Pb^{206}-α-2n (2T47a); Pb^{207}-α-3n (2T47a); Bi-d-3n (2T47a, 10K49); Bi-p-2n (4L47); daughter Em^{212}, daughter 1.7 h At^{208} (8H50); daughter 7.0 h At^{208} (12B51)
Po^{209}	A chem, excit (10K49)		α ≥90%, EC ≤10% est (13P50)	~100 y yield (10K50)	4.877 spect (4A52b); 4.86 ion ch (7K51a)	0.87 (1%), 0.55 (0.5%), 0.2 (0.2%), 0.1 (0.07%) scint spect (18H51)	Q_α 4.972 (13S53)	Bi-d-2n (10K49)
Po^{210}	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	138.3 d (5B49); 140 d (1C31)	5.298 spect (9H38, 16S51); 5.303 spect (7C46); ~4.5 (weak) α-γ coinc, scint spect (10D52)	γ_1 0.800 (e/γ ~0.03, K/L 3.7) spect, spect conv (13A51a); γ_1 0.804 scint spect (18P52); γ_1 0.784 spect conv (10C51); γ_1 0.773 spect (7S47a); γ_1 (1.8 x 10^{-3}%, e/γ ~0.07), no 0.08 γ ion ch, crit abs, γ-γ coinc (7G51); γ_1 (1.6 x 10^{-3}%) abs (3R52); 0.77 (~10^{-3}%), 0.084 (~10^{-3}%) abs (1Z48); others (10D47, 49R52, 63B52)	Q_α 5.401 (13S53)  Po^{210} α ~10^{-3}% ~100% (2+) 0.800 (0+) 0 (7G51, 10D52)	natural source, daughter Bi^{210} (RaE); Pb^{208}-α-2n (2T47a); Bi-d-n (47H40, 10C40); Bi-p-γ (10K50); daughter At^{210} (10K49); daughter (long-lived) Bi^{210} (52L52)
Po^{211} (AcC')	A genet (1C31)		α; β stable (cons energy) (HPS)	0.52 s (13L51)	7.434 spect (11L34); 6.88 (0.50%), 6.56 (0.53%), no 6.34 α (lim 0.02%) spect (74H52a); 6.90 (0.6%), 6.57 (0.5%), 6.34 (0.1%) ion ch (4N51)		Q_α 7.58 (13S53) see Bi^{207}	natural source, daughter Bi^{211} (AcC); daughter At^{211} (11C40, 11C40a); daughter Em^{215} (11M52); not parent Pb^{207m} (23F52a)
Po^{211}	D chem, excit, sep isotopes (114S51)		α (114S51)	25 s (114S51)	7.14 ion ch (114S51)			Pb^{208}-α-n (114S51)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{84}$Po^{212} (ThC')	A genet (1C31)		α	3. 04 x 10^{-7} s delay coinc (4B49); 3. 0 x 10^{-7} s delay coinc (11H48); others (3J48, 4V49, 11D39, 16B43)	8. 776 spect (15B36, 9H38); long range α's: 10. 536 (0. 017%), 10. 417 (0. 002%), 9. 489 (0. 004%) spect (48R51)		Q$_α$ 8. 946 (13S53)	natural source, daughter Bi^{212} (ThC); daughter Em^{216} (11M49)
Po^{213}	A genet (4H47, 11E47)		α (4H47, 11E47)	4. 2 x 10^{-6} s delay coinc (3J48)	8. 336 ion ch (11E47, 5C48); 8. 34 ion ch (4H50a)		Q$_α$ 8. 496 (13S53)	daughter Bi^{213}, parent Pb^{209} (4H47, 11E47); daughter Em^{217} (11M49)
Po^{214} (RaC')	A genet (1C31)		α; β stable (cons energy) (HPS)	1. 637 x 10^{-4} s delay coinc (13D50); ~1. 5 x 10^{-4} s delay coinc (11D39, 6R41, 5W42, 4J43, 14L47, 4B48); 1. 4 x 10^{-4} s delay coinc (5R47)	7. 680 spect (15B36, 9H38); 7. 683 spect (16S51); long range α's: 9. 069 (0. 002%), others 8. 280-10. 509 spect (11L34)		Q$_α$ 7. 826 (13S53)	natural source, daughter Bi^{214} (RaC), parent Pb^{210} (RaD); daughter Em^{218} (4S48)
Po^{215} (AcA)	A genet (1C31)		α 99+%, β$^-$ 5 x 10^{-4}% (5K44, 8A50)	1. 83 x 10^{-3} s delay coinc (5W42)	7. 365 spect (11L34)		Q$_α$ 7. 505, Q$_β^-$ 0. 8 calc (13S53)	natural source, daughter Em^{219} (An), parent Pb^{211} (AcB); parent At^{215} (5K44)
Po^{216} (ThA)	A genet (1C31)		α; β stable (cons energy) (HPS); α 99+%, β$^-$ 0. 014% (5K43)	0. 158 s (5W42)	α: 6. 774 spect (15B36, 9H38)		Q$_α$ 6. 902 (13S53)	natural source, daughter Em^{220} (Tn), parent Pb^{212} (ThB); parent At^{216} (5K43) (?)
Po^{217}	C genet (9M52b)		α (9M52b)		6. 5 ion ch (9M52b)		Q$_α$ 6. 7, Q$_β^-$ 1. 3 est (13S53)	daughter Em^{221} (9M52b)
Po^{218} (RaA)	A chem, genet (1C31)		α 99+%, β$^-$ 0. 03% (5K43a)	3. 05 m (1C31)	α: 5. 998 spect (15B36, 9H38)		Q$_α$ 6. 110, Q$_β^-$ 0. 33 calc (13S53)	natural source, daughter Em^{222} (Rn), parent Pb^{214} (RaB); parent At^{218} (5K43a)
$_{85}$At$^{<202}$	D chem, excit (12B51)		α, EC (12B51)	43 s (12B51)	6. 50 ion ch (12B51)			Bi-α-spall (12B51)
At$^{<203}$	D chem, excit (12B51)		α, EC (12B51)	1. 7 m (12B51)	6. 35 ion ch (12B51)			Bi-α-spall (12B51)
At^{203}	D chem, excit (12B51)		α, EC (12B51)	7 m (12B51, 13H51)	6. 10 ion ch (12B51)			Bi-α-10n (12B51); Au-C-6n (13H51, 4M50)
At^{204}	B chem, excit, genet (12B51)		EC (12B51)	~25 m genet (12B51)				Bi-α-9n, parent Po^{204} (12B51)
At^{205}	B chem, excit, genet (12B51)		α, EC (12B51)	25 m (12B51, 13H51)	5. 90 ion ch (12B51)			Bi-α-8n, parent Po^{205} (12B51); Au-C-4n (4M50, 13H51)
At^{206}	B chem, excit, genet (12B51)		EC (12B51)	2. 6 h genet (12B51)				Bi-α-7n, parent Po^{206} (12B51)

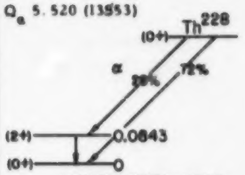
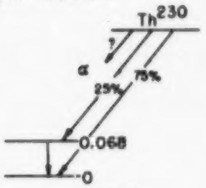
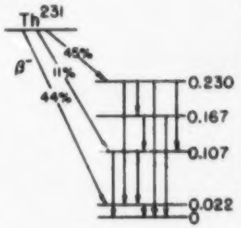
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{85}\mathrm{At}^{207}$	B chem, excit, genet (2T48a, 12B51)		EC ~90%, α ~10% (2T48a, 12B51)	2.0 h (12B51)	5.75 ion ch (12B51)			Bi-α-6n (2T48a, 12B51); parent Po^{207}, parent Bi^{203} (12B51)
At^{208}	B chem, excit, genet (12B51)		EC (12B51)	6.3 h genet (12B51)				Bi-α-5n, parent Po^{208} (12B51)
At^{208}	A chem, genet (8H50)		EC 99+%, α 0.5%(8H50)	1.7 h (8H50)	5.65 ion ch (8H50)			daughter Fr^{212}, parent Po^{208} (8H50, 9M52a)
At^{209}	B chem, genet, excit (12B51)		EC ~95%, α ~5% (12B51)	5.5 h (12B51)	5.65 ion ch (12B51)	0.2, 0.8 scint spect (89M52)		Bi-α-4n, parent Po^{209}, parent Bi^{205} (12B51)
At^{210}	A chem, excit, genet (10K49)		EC 99+%, α 0.17% (74H52a); EC 99+%, α 0.1% (4N50b)	8.3 h (10K49)	5.519 (32%), 5.437 (31%), 5.355 (37%) spect (74H52a)	0.25, 1.15, 1.40 scint spect (74H52a); 1.0 abs, abs conv (10K49)		Bi-α-3n, parent Po^{210} (10K49, 12B51); parent Bi^{206} (4N50b)
At^{211}	A chem, excit, genet (11C40, 10K49)		α 40.9%, EC 59.1% (4N51)	7.5 h (11C40, 10K49); 7.3 h (17H51)	5.862 spect (74H52a); 5.89 ion ch (2T48a, 12B51)		Q_α 5.975, Q_{EC} 0.9 est (13S53)	Bi-α-2n (11C40, 11C40a, 10K49, 12B51); spall Th, U (20B52, 13S47)
At^{212}	E excit (7W48)		α (7W48)	0.25 s (7W48)				Bi-α-n (7W48)
At^{213}	E genet, decay charac (57K51)		α (57K51)		9.2 range emuls (57K51)			descendent Pa^{225} (57K51)
At^{214}	B genet (11M49)		α (11M49)	~2 x 10^{-6} s est (11M51)	8.78 ion ch (11M49, 11M51)		Q_α 8.95, Q_{EC} 1.05 calc (13S53)	daughter Fr^{218} (11M49, 11M51)
At^{215}	A genet (5K44, 13G48)		α (5K44, 13G48)	~10^{-4} s delay coinc (13G48, 11M51); short (5K44)	8.00 ion ch (13G48, 11M51); 8.4 ion ch (5K44)		Q_α 8.15, Q_β^- 0.0 calc (13S53)	daughter Fr^{219}, parent Bi^{211} (AcC) (13G48, 11M51); natural source, daughter Po^{215} (AcA), parent Bi^{211} (AcC) (5K44)
At^{216}	A genet (13G48)		α (5K43, 13G48)	~3 x 10^{-4} s delay coinc (11M49, 11M51); short (<54 s) (5K43)	7.79 ion ch (13G48, 11M51); 7.64 ion ch (5K43)		Q_α 7.94, Q_β^- 2.03 calc, Q_{EC} 0.46 calc (13S53)	daughter Fr^{220}, parent Bi^{212} (ThC) (13G48, 11M51); natural source, parent Bi^{212} (ThC) (5K43); daughter Po^{216} (ThA) (5K43); note Po^{216} β-stable (HP8)
At^{217}	A genet (11E47, 4H47)		α (11E47, 4H47)	0.018 s delay coinc (4H47, 4H50a); 0.021 s delay coinc (11E47)	7.02 ion ch (5C48); 7.00 ion ch (4H47)		Q_α 7.15, Q_β^- 0.65 calc (13S53)	daughter Fr^{221}, parent Bi^{213} (11E47, 4H47, 4H50a)
At^{218}	E genet (5K43a)		α (5K43a); α 99+%, β^- 0.1% (3W48)	1.5-2.0 s (3W48); several sec (?) (5K43a)	α: 6.63 range (5K43a); 6.7 ion ch (3W48)		Q_α 6.75, Q_β^- 2.67 calc (13S53)	natural source, daughter Po^{218} (RaA), parent Bi^{214} (RaC) (5K43a, 3W48)
At^{219}	A chem, genet (8H53)		α ~97%, β^- ~3% (8H53)	0.9 m (8H53)	α: 6.27 ion ch (8H53)		Q_α 6.39, Q_β^- 1.45 est (13S53)	natural source, daughter Fr^{223} (AcK), parent Em^{219} (An), parent Bi^{215} (8H53)

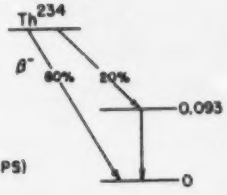
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{86}Em^{208}$	D chem (9M52b)		EC ~80%, α ~20% (9M52b)	23 m (9M52b)	6.138 spect (9M52)			spall Th (9M52b)
Em^{209}	B chem, genet (9M52a)		EC ~80%, α ~20% (9M52a)	30 m (9M52b)	6.02 ion ch (9M52a)			Pb-C-spall, spall Th (9M52a); daughter Ra^{213}, parent At^{209} (9M52a)
Em^{210}	B chem, genet (9M52a)		α >95%, EC <5% (9M52b)	2.7 h (9M52a); 2.1 h (13G49)	6.036 spect (9M52); 6.02 ion ch (9M52a)		Q_α 6.153 (13S53)	spall Th (13G49, 9M52a); Pb-C-spall (9M52a); parent Po^{206} (9M52a)
Em^{211}	A chem, genet (9M52a)		EC 75%, α 25% (9M52a)	16 h (9M52a)	5.847 (33%), 5.778 (67%) spect (9M52); 5.82 ion ch (9M52a)			Pb-C-spall, parent At^{211} (9M52a)
Em^{212}	A chem, genet (8H50, 13G49)		α (8H50)	23 m (13G49, 8H50, 9M52a)	6.262 spect (9M52); 6.23 ion ch (9M52a)		Q_α 6.382 (13S53)	spall Th (13G49); daughter Fr^{212}, parent Po^{208} (8H50, 9M52a)
Em^{215}	B genet (11M52)		α (11M52)	~10^{-6} s est (11M52)	8.6 ion ch (11M52)			daughter Ra^{219}, parent Po^{211} (AcC') (11M52)
Em^{216}	A genet (11M49, 11M51)		α (11M49, 11M51); β stable (cons energy) (HPS)	~10^{-4} s est (11M51)	8.01 ion ch (7O50)		Q_α 8.16 (13S53)	daughter Ra^{220}, parent Po^{212} (ThC') (11M49, 11M51)
Em^{217}	A genet (11M49, 11M51)		α (11M51); β stable (cons energy) (HPS)	~10^{-3} s delay coinc (11M51)	7.74 ion ch (11M51)		Q_α 7.89 (13S53)	daughter Ra^{221}, parent Po^{213} ([illegible], 11M51)
Em^{218}	A genet (4S48)		α (4S48); β stable (cons energy) (HPS)	0.019 s delay coinc (4S48)	7.12 ion ch (1J48)		Q_α 7.25 (13S53)	daughter Ra^{222}, parent Po^{214} (RaC') (4S48)
Em^{219} (An)	A chem, genet (1C31)		α	3.92 s (1C31)	6.824, 6.559, 6.434 spect (11L34); α_0 (69%), α_{270} (15%), α_{397} (12%), α_{622} (4%) spect (4R36)	0.067, 0.124, 0.198 (strong), 0.267, 0.321, 0.392, 0.589 (weak) spect conv (11S37); 0.123, 0.270, 0.590 cryst spect (8F40)	Q_α 6.951, Q_β^- 0.26 calc (13S53)  Em^{219} α 12% 15% 4% 69% 0.622 0.397 0.270 0.067 0 (4R36, HPS)	natural source, daughter Ra^{223} (AcX), parent Po^{215} (AcA); daughter At^{219} (8H53)
Em^{220} (Tn)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	54.5 s (1C31)	6.282 spect (15B36, 9H38)		Q_α 6.398 (13S53)	natural source, daughter Ra^{224} (ThX), parent Po^{216} (ThA)
Em^{221}	A chem, genet (9M52a)		β^- ~80%, α ~20% (9M52b)	25 m (9M52b)			Q_α 6.0 est, Q_β^- 0.9 est (13S53)	Th-p-spall, parent Fr^{221} (9M52a); parent Po^{217} (9M52b)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{86}$Em^{222} (Rn)	A chem, genet (1C31)		α; no β^- (lim 10^{-4}%) (5K46)	3.825 d (22T51, 1C31)	5.486 spect (15B36, 9H38)		Q_α 5.587 (13S53)	natural source, daughter Ra^{226}, parent Po^{218} (RaA)
$_{87}$Fr^{212}	A chem, genet (8H50); chem, mass spect (9M52a)		EC 56%, α 44% (8H50)	19.3 m (8H50)	6.409 (37%), 6.387 (39%), 6.339 (24%) spect (8H52c); 6.36 ion ch (8H51)			spall Th (8H50); parent Em^{212} (8H50, 9M52a)
Fr^{217}	E genet, decay charac (57K51)		α (57K51)		8.3 range emuls (57K51)			descendent Pa^{225} (57K51)
Fr^{218}	B genet (11M49, 11M51)		α (11M51)	5 x 10^{-3} s est (11M51)	7.85 ion ch (11M51)		Q_α 8.00, Q_{EC} 1.8 calc (13S53)	daughter Ac^{222}, parent At^{214} (11M49, 11M51)
Fr^{219}	A genet (13G48)		α (13G48); β stable (cons energy) (HPS)	0.02 s delay coinc (11M51)	7.30 ion ch (11M51)		Q_α 7.44 (13S53)	daughter Ac^{223}, parent At^{215} (13G48, 11M49, 11M51)
Fr^{220}	A genet (13G48)		α (13G48)	27.5 s (11M51)	6.69 ion ch (11M51)		Q_α 6.81, Q_β^- 1.27 calc, Q_{EC} 0.87 calc (13S53)	daughter Ac^{224}, parent At^{216} (13G48, 11M49, 11M51)
Fr^{221}	A chem, genet (4H47, 11E47)		α (11E47, 4H47)	4.8 m (4H50a); 5 m (11E47)	6.30 ion ch (4H47, 5C48); 6.30 (~75%), 6.05 (~25%) ion ch (4H50a)	0.220 spect conv, scint spect (39W53)	Q_α 6.42, Q_β^- 0.24 calc (13S53)	daughter Ac^{225}, parent At^{217} (11E47, 4H47, 5C48, 4H50a); daughter Em^{221} (9M52a)
Fr^{222}	A chem, genet (8H50a)		β^- 99+%, α 0.01-0.1% (8H51a)	14.8 m (8H50a)			Q_α 6.00 est, Q_β^- 2.04 est, Q_{EC} 0.02 est (13S53)	spall Th, parent Ra^{222}, ancestor Bi^{214} (8H50a, 8H51a)
Fr^{223} (AcK)	A chem, genet (7P39, 7P39b)		β^- (7P39a, 8G47); α 4 x 10^{-3}% (8H53)	21 m (7P39)	β^-: 1.2 cl ch (7P39a, 7P39b, 6L50)	0.09 abs (6L44, 7P46); ~0.330 (6%) abs, 0.0486 (27%) crit abs (6L50)	Q_α 5.60 est, Q_β^- 1.19 calc (13S53)	natural source, daughter Ac^{227}, parent Ra^{223} (AcX) (7P39, 7P39a, 7P39b, 7P41, 7P46, 8G47, 6L50); parent At^{219} (8H53)
$_{88}$Ra^{213}	B chem, genet (9M52a)		α (9M52a)	2.7 m (9M52c)	6.90 ion ch (9M52c)			Pb-C-spall, spall Th, parent Em^{209} (9M52a)
Ra^{219}	B genet (11M52)		α (11M52)	~10^{-3} s est (11M52)	8.0 ion ch (11M52)		Q_α 8.1 (13S53)	daughter Th^{223}, parent Em^{215} (11M52)
Ra^{220}	A genet (11M49, 11M51)		α (11M51)	3 x 10^{-2} s est (11M51)	7.43 ion ch (7O50)		Q_α 7.57 (13S53)	daughter Th^{224}, parent Em^{216} (11M49, 11M51)
Ra^{221}	A chem, genet (11M49, 11M51)		α (11M51)	30 s (11M51)	6.71 ion ch (11M51)		Q_α 6.83 (13S53)	daughter Th^{225}, parent Em^{217} (11M49, 11M51)
Ra^{222}	A chem, genet (4S48)		α (4S48); β stable (cons energy) (HPS)	38 s (4S48)	6.51 ion ch (1J48)		Q_α 6.63 (13S53)	daughter Th^{226}, parent Em^{218} (4S48); daughter Fr^{222} (8H51a)

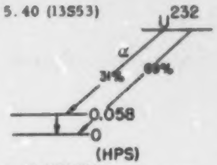
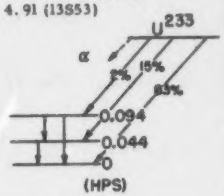
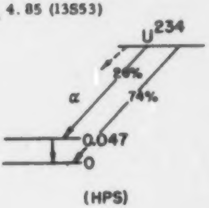
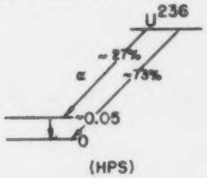
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{88}Ra^{223}$ (AcX)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	11.2 d (1C31)	5.860 (weak), 5.730 (9%), 5.704 (53%), 5.596 (24%), 5.528 (9%), 5.487 (2%), 5.419 (3%) spect (4R52b); 5.750 (11%), 5.719 (53%), 5.607 (25%), 5.540 (9%), 5.433 (2%) spect (4A52a); no 6.0-6.1 α (lim 0.5%) (13H50); others (11L34, 4R36, 4R37)	0.144, 0.155, 0.180, 0.270, 0.340 cryst spect (8F40); 0.026, 0.064, 0.081, 0.099, 0.116, 0.154, 0.164, 0.180, 0.232, 0.268, 0.280, 0.322, 0.348, 0.444 spect conv (11S37)	Q_α 5.855 (13S53)	natural source, daughter Th^{227} (RdAc), daughter Fr^{223} (AcK), parent Em^{219} (An); daughter Ac^{223} (11M51); spall U (13S47, 6O47, 6F51)
Ra^{224} (ThX)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	3.64 d (1C31)	5.681 (95%), 5.448 (4.6%), 5.194 (0.4%) spect (4R49); 5.681 spect (15B36); 5.66 ion ch (2C45)	0.241 (e_K/γ 0.1) spect conv (4R52); no γ (1M28, 4F49)	Q_α 5.784 (13S53)  Ra^{224} α 4.6% 0.4% 95% 0.495 0.241 0 (4R52, HPS)	natural source, daughter Th^{228} (RdTh), parent Em^{220} (Tn); spall U (13S47, 6O47, 6F51)
Ra^{225}	A chem, genet (11E47, 4H47)		β^- (11E47, 4H47); no α (lim 0.1%) (9M52c)	14.8 d (4H50a); 14 d (11E47)	~0.31 spect (3F52a); ~0.2 abs (4H50a); <0.05 abs (11E47)			daughter Th^{229}, parent Ac^{225} (11E47, 4H47, 4H50a); spall U (6F51)
Ra^{226}	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	1622 y sp act (2K49a); 1631 y sp act (3C46); 1590 y sp act (1C31)	α_0 4.777 spect (4R52b); α_0 (94.3%), α_{188} (5.7%) spect (4A52c); α_0 (95.2%), α_{186} (4.8%) ion ch (7K51a); α_0 (93.5%), α_{187} (6.5%) spect (4R49a); others (109B51)	0.186 spect conv (10C51); ~0.19 (e/γ 0.88, K/L ~0.5) α-conv coinc abs (14V52); 0.188 (16H24, 7R36); (e/γ ~0.5) (8S43)	Q_α 4.863 (4R52b)  (4A52a, HPS)	natural source, daughter Th^{230} (Io), parent Em^{222} (Rn)
Ra^{227}	A n-capt, genet (8P49)		β^- (8P49, 6F50)	41.2 m (107B52)	1.30 spect (107B52)	0.291, 0.498 scint spect (107B52)		Ra-n-γ, parent Ac^{227} (8P49); spall U (6F50)
Ra^{228} ($MsTh_1$)	A chem, genet (1C31)		β^-	6.7 y (1C31)	~0.012 (?) cl ch (6L48, 6L49a); 0.053 spect, abs (8L39)	~0.03 cl ch (6L48, 6L49)	Q_β^- ~0.04 (13S53)	natural source, daughter Th^{232}, parent Ac^{228} ($MsTh_2$)
Ra^{229}	[B] n-capt, genet (41D52)		[β^-] (41D52)	[short] (41D52)				[Ra^{228}-n-γ, parent Ac^{229}] (41D52)
Ra^{230}	D chem (5J52)		β^- (5J52)	1 h (5J52)	1.2 abs, spect (5J52)			spall Th, parent Ac^{230} (5J52)
$_{89}Ac^{221}$	E genet, decay charac (57K51)		α (57K51)		7.6 range emuls (57K51)			descendent Pa^{225} (57K51)
Ac^{222}	B genet (11M49, 11M51)		α (11M51)	5.5 s (11M52)	6.96 ion ch (11M51)		Q_α 7. Q_{EC} 2.26 calc (13S53)	daughter Pa^{226}, parent Fr^{218} (11M49, 11M51)
Ac^{223}	A genet (13G48)		α 99%, EC 1% (11M51)	2.2 m (11M51)	6.64 ion ch (11M51)		Q_α 6.76, Q_{EC} 0.64 calc (13S53)	daughter Pa^{227}, parent Fr^{219}, parent Ra^{223} (AcX) (13G48, 11M49, 11M51)
Ac^{224}	A chem, genet (13G48)		EC ~90%, α ~10% (11M51)	2.9 h (11M51)	6.17 ion ch (11M51)		Q_α 6.28, Q_{EC} 1.37 calc, Q_β^- 0.29 calc (13S53)	daughter Pa^{228}, parent Fr^{220}, parent Ra^{224} (ThX), (13G48, 11M49, 11M51)

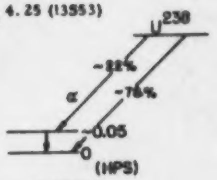
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{89}Ac^{225}$	A chem, genet (4H47, 11E47)		α (11E47, 4H47); β stable (cons energy) (HPS)	10.0 d (4H50a, 11E47)	5.80 ion ch (4H50a, 5C48)		Q_α 5.90 (13S53)	daughter Ra^{225}, parent Fr^{221} (4H47, 11E47, 4H50a); daughter Pa^{229} (8H49a); daughter Th^{225} (11M49, 11M51); spall Th (17H50), U (6O47)
Ac^{226}	A chem, genet (6S48)		β^- (6S48)	29 h (6S50)	1.17 abs (17H50)		Q_α 5.44 est, Q_{EC} 0.6 est, Q_β^- 1.07 est (13S53)	spall U, daughter Pa^{230}, parent Th^{226} (6S48, 6S50); spall Th (17H50, 11M50); daughter Pa^{230}, parent Th^{226} (11M50)
Ac^{227}	A chem, genet (1C31)		β^- ~99% (7P39, 8P49a); α 1.2% (2M14, 7P39, 7P46, 8P49a)	22.0 y (13H50a); 21.7 y (4C44); 13.5 y (1C31)	α: 4.942 spect (4R52b); 4.94 (100%) ion ch (13G48a); others (3G47) β^-: 0.04 spect (3F50); ~0.02 cl ch (7P46); <0.03 abs (6L44)	0.037 (weak) abs (6L43, 6L44, 7P46); (0.2%) (6L50)	Ac^{227}, I = 3/2 (36T51) Q_α 5.03, Q_β^- -0.08 calc (13S53)	natural source, daughter Pa^{231}, parent Th^{227} (RdAc); parent Fr^{223} (AcK) (7P39, 7P46); daughter Ra^{227} (8P49)
Ac^{228} ($MsTh_2$)	A chem, genet (1C31)		β^-	6.13 h (1C31)	2.18 (10%), 1.85 (9%), 1.72 (7%), 1.15 (53%), 0.66 (8%), 0.46 (13%) spect (82C52); 2.03, 1.74, 1.10 spect (5J51); others (4F38, 6L38, 3L39)	0.058, 0.129, 0.184, 0.338, 0.462, 0.914, 0.969 spect conv (13B24); 0.333, 0.462, 0.913, 0.968 spect (5T26); 0.063, 0.146, 0.186, 0.338, 0.533, 0.590, 0.905 spect conv (5J51)	Q_α 4.66 est, Q_β^- 2.18 (13S53)	natural source, daughter Ra^{228} ($MsTh_1$), parent Th^{228} (RdTh)
Ac^{229}	B chem, n-capt (41D52)		β^- (41D52)	66 m (41D52)			Q_β^- 1.0 est (13S53)	daughter Ra^{229} (41D52)
Ac^{230}	F genet (5J52)		β^- (5J52)	<1 m genet (5J52)	~2.2 abs, spect (5J52)			daughter Ra^{230} (5J52)
$_{90}Th^{223}$	B genet (11M52)		α (11M52)	~0.1 s est (11M52)	7.55 ion ch (11M52)		Q_α 7.69 (13S53)	daughter U^{227}, parent Ra^{219} (11M52)
Th^{224}	A genet (11M49, 11M51)		α (11M51); β stable (cons energy) (HPS)	~1 s est (11M51)	7.13 ion ch (7O50)		Q_α 7.26 (13S53)	daughter U^{228}, parent Ra^{220} (11M49, 11M51)
Th^{225}	A chem, genet (11M49, 11M51)		α ~90%, EC ~10% (11M51)	8.0 m (11M51)	6.57 ion ch (11M51)		Q_α 6.69, Q_{EC} 0.55 calc (13S53)	daughter U^{229}, parent Ra^{221}, parent Ac^{225} (11M49, 11M51)
Th^{226}	A chem, genet (4S48)		α (4S48); β stable (cons energy) (HPS)	30.9 m (4S48)	α_0 (78%), α_{117} (22%) spect (21S52); 6.30 ion ch (1J48)		Q_α 6.41 (13S53)	daughter U^{230}, parent Ra^{222} (4S48); daughter Ac^{226} (6S48, 6S50)

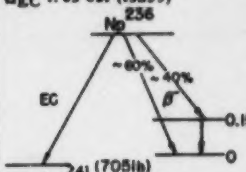
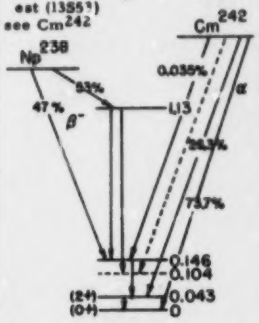
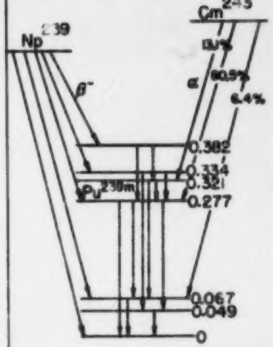
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev: Particles	Energy of radiation in Mev: Gamma-transitions	Disintegration energy and scheme	Method of production and genetic relationships
$_{90}Th^{227}$ (RdAc)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	18.6 d (8P49b); 18.9 d (1C31)	6.030 (19%), 6.001 (5%), 5.972 (21%), 5.952 (13%), 5.922 (-2%), 5.860 (4%), 5.796 (2%), 5.749 (17%), 5.728 (-1%), 5.704 (15%), 5.651 (-2%) spect (4R52b); 6.049 (20%), 6.017 (4%), 5.988 (25%), 5.966 (4%), 5.922 (-1%), 5.868 (2.5%), 5.815 (-1%), 5.764 (20%), 5.742 (4%), 5.717 (15%), 5.672 (2.5%) spect (11L34)	0.050, 0.057, 0.080, 0.101, 0.113, 0.129, 0.208, 0.240, 0.258 cryst spect (8F40); 0.050 (3%), 0.120 (13%), 0.280 (50%) abs (3R50); 0.050 (5%), 0.125 (10%), 0.270 (26%) abs (3B44); 0.050 (-3%), 0.125 (23%) abs (9T42)	Q_α 6.138 (13S53)	natural source, daughter Ac^{227}, parent Ra^{223} (AcX); daughter Pa^{227} (13G48, 11M51); spall U (6O47)
Th^{228} (RdTh)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	1.90 y (1C31)	5.423 (72%), 5.338 (28%) spect (4R49b)	0.0843 spect conv (4R52a); 0.083 (e/γ 12) α-conv coinc abs (14V52); 0.083 (2.1%, e/γ ≈ 10) crit abs (3R53); others (1M28, 11S41a, 3R50, 103B51)	Q_α 5.520 (13S53)  (0+) Th^{228} α 28% 72% (2+) 0.0843 (0+) 0 (4R49b, 4R52a,HPS)	natural source, daughter Ac^{228} ($MsTh_2$), parent Ra^{224} (ThX); daughter U^{232} (9G49); daughter Pa^{228} (13G48b, 11M51)
Th^{229}	A chem, genet (11E47, 4H47)		α; β stable (cons energy) (HPS)	7340 y genet (4H50a); $\sim 10^4$ y genet (11E47)	5.02 (-10%), 4.94 (-20%), 4.85 (-70%) ion ch (4H50a)		Q_α 5.11 (13S53)	daughter U^{233}, parent Ra^{225} (11E47, 4H47, 4H50a)
Th^{230} (Io)	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	8.0×10^4 y sp act (8H49b); 8.2×10^4 y genet (1C30)	4.682 (-75%), 4.613 (-25%), 4.51 (?) (weak) spect (4R48); 4.66 range air (1G22), ion ch (2C44, 2C45)	0.068, 0.228 (very weak) spect conv (4R51); 0.068 (0.85%), 0.140 (0.33%), 0.240 (0.05%) abs (4C48); -0.07 (coinc with α, e/γ -46) α-conv coinc abs (14V52, 10F51); -0.068 (0.5%), 0.190 (0.3%) abs (3R50); -0.07 (coinc with α), -0.2 (coinc with α) α-γ, α-conv coinc abs (5P51); others (6J51, 5W39)	Q_α 4.765 (13S53)  (HPS)	natural source, daughter U^{234} (U_{II}), parent Ra^{226}; daughter Pa^{230} (4S48a)
Th^{231} (UY)	A chem, genet (1C31)		β^-	25.64 h (1J51); 25.5 h (3K49); 24.6 h (1C31); 24.0 h (12G32)	0.302 (44%), 0.216 (11%), 0.094 (45%) spect (3F52); 0.39 (-20%), 0.19 (-40%), 0.10 (-40%) spect (10S51); 0.2 abs (5E37, 1J51)	γ_1 0.022, γ_2 0.059, γ_3 0.063, γ_4 0.085, γ_5 0.107, γ_6 0.122, γ_7 0.167, γ_8 0.208, γ_9 0.230 ($\gamma_2+\gamma_3/\gamma_4/\gamma_5/\gamma_6/\gamma_7/\gamma_8/\gamma_9$ = 0.40/1.00/0.065/0.02/0.018/0.003/0.001) spect conv, scint spect (3F52); 0.059, 0.063, 0.082, 0.120 spect conv (10S51); 0.035 (>80%), 0.210 abs (3K49)	Q_α 4.19 calc (13S53) Q_β^- 0.324 (3F52)  Th^{231} β^- 45% 11% 44% 0.230 0.167 0.107 0.022 0 (3F52)	natural source, daughter U^{235} (AcU), parent Pa^{231}; Th-n-2n (5N38, 13S52)
Th^{232}	A chem, genet (1C31)	100 (1A35, 1D36)	α; β stable (cons energy) (HPS)	1.39×10^{10} y sp act (6K38); spont fission: 1.4×10^{18} y (24S52)	3.98 ion ch (2C45); 3.98 range emuls (7F51a); 4.20 ion ch (1S37)	-0.055 (coinc with 24% of α) α-conv coinc emuls (15D52); -0.075 (coinc with -20% of α) α-conv coinc emuls (5A52)	Q_α 4.05 (13S53)	natural source, parent Ra^{228} ($MsTh_1$)

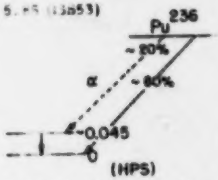
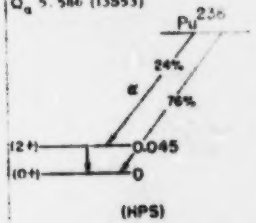
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{90}Th^{233}$	A chem, n-capt (1M38)		β^- (13S47a)	23. 3 m (2B50); 23. 5 m (13S47a); 23. 6 m (31R52); 23 m (2G41)	1. 23 spect (2B50, 31P52); 1. 24 spect (3F53); 1. 2 abs (13S52)	0. 098 (0. 25%), 0. 172 (0. 03%), 0. 350 (0. 004%), 0. 448 (0. 1%), 0. 662 (^. 05%) scint spect (3F53); no γ (2B50, 31R52)	Q_α 3. 79 est, Q_β^- 1. 23 (13S53)	Th-n-γ (1M38, 13S47a, 13S41, 2G41); Th-d-p (9G49); parent Pa^{233} (1M38)
Th^{234} (UX_1)	A chem, genet (1C31)		β^-	24. 10 d (3K48); 24. 1 d (3S39); 24. 5 d (1C31)	0. 205 (~80%), 0. 111 (~20%) spect (16B46); 0. 192 (56%), 0. 104 (44%) spect (19H50); 0. 190 spect (7J46); 0. 20, 0. 1 abs (4F38a)	0. 090 (e/γ ~0. 2) spect conv (19H50); 0. 093 (~20%, e_L/γ ~0. 34), 0. 180 (4. 5%) spect conv, abs (16B46); 0. 092 (1M23)	Q_β^- 0. 20 (13S53)  (HPS)	natural source, daughter U^{238}, parem Pa^{234} (UX_2)
Th^{235}	[B] n-capt, genet (20H50)		[β^-] (20H50)	<<10 m genet (20H50)				[Th^{234}-n-γ, parent Pa^{235}] (20H50)
$_{91}Pa^{225}$	E excit, decay charac (57K51)		α (57K51)	2. 0 s (57K51)				spall Th, ancestor Ac^{221}, Fr^{217}, At^{213} (57K51)
Pa^{226}	B chem, genet (11M49, 11M51)		α (11M51)	1. 8 m (11M51)	6. 81 ion ch (11M51)		Q_α 6.93, Q_{EC} 2.8 calc (13S53)	spall Th, parent Ac^{222} (11M49, 11M51, 11M52)
Pa^{227}	A chem, genet (13G48)		α ~85%, EC ~15% (11M51)	38. 3 m (11M51)	6. 46 ion ch (11M51)		Q_α 6. 58, Q_{EC} 1. 08 calc (13S53)	spall Th, parent Ac^{223}, parent Th^{227} (RdAc) (13G48, 11M51); daughter Np^{231} (13G48b); spall U (6O48)
Pa^{228}	A chem, genet (13G48)		EC ~98%, α ~2% (11M51)	22 h (11M51)	6. 09 (75%), 5. 85 (25%) ion ch (11M51)		Q_α 6. 20, Q_{EC} 2. 05 calc (13S53)	spall Th, daughter U^{228}, parent Ac^{224}, parent Th^{228} (RdTh) (13G48, 11M49, 11M51)
Pa^{229}	A chem, genet (8H49a)		EC 99+%, α 0. 25% (21S51); EC ~99%, α ~1% (11M51)	1. 5 d (8H48)	5. 69 ion ch (11M48); 5. 66 ion ch (8H48)		Q_α 5. 79, Q_{EC} 0. 37 calc (13S53)	Th^{230}-d-3n, parent Ac^{225} (8H49a); daughter U^{229} (11M51)
Pa^{230}	A chem, genet, excit (4S48)		EC ~92%, β^- ~8% (4S49); α ~0. 003% (11M50)	17. 7 d (5O49); 17. 0 d (4S48)	β^-: ~0. 43 abs (5O49)	0. 94 abs (5O49)	Q_α 5. 45 est, Q_β^- 0. 57 est, Q_{EC} 1. 28 est (13S53)	Th-d-4n, Th-α-p5n, parent U^{230} (4S48); Th^{230}-d-2n (8H49a); Pa-d-p2n, Pa-α-αn (5O49); U^{233}-d-αn (8H49); parent Th^{230} (Io), parent Ac^{226} (11M50)
Pa^{231}	A chem, genet (1C31)		α; β stable (cons energy) (HPS)	3. 43 x 10^4 y sp act (8W49); 3. 2 x 10^4 y sp act (2G30)	5. 042 (11%), 5. 002 (47%), 4. 938 (25%) 4. 838 (3%), 4. 720 (11%), 4. 66[illegible] (1-3%) spect (4R49c, 13C[illegible]); ~5. 0 (85%), ~4. 7 (15%) ion ch (2C44, 9T46a, 13G48a)	0. 034, 0. 038, 0. 057, 0. 064, 0. 082, 0. 102, 0. 198, 0. 259, 0. 301, 0. 331, 0. 357, 0. 383 spect conv (10F52a); 0. 095, 0. 294, 0. 323 spect conv (1M28a); 0. 027 (9%), 0. 087, 0. 100, 0. 30 (4%) abs, crit abs (3R52a); 0. 044, 0. 066 cl ch (4T52); 0. 027 crit abs, ion ch (17S51); others (4S46, 4T49)	Pa^{231}, I = 3/2 (87M50) Q_α 5. 131 (13S53)	natural source, daughter Th^{231} (UY), parent Ac^{227}; Th-d-3n (4S48); daughter U^{231} (14C50)

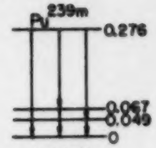
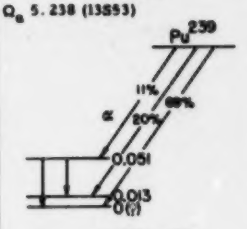
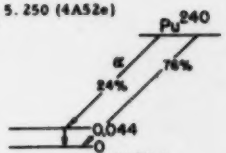
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{91}Pa^{232}$	A chem, genet (9G49)		β^- (9G49); no EC (lim 2%) (88B52a)	1.32 d (1J50); 1.4 d (5O49); 1.6 d (9G49)	0.99 (-30%), 0.64 (-10%), 0.28 (-60%) spect (35P52); -0.28 abs (1J48b)	-0.23 (-30%), 1.05 (-100%) abs (1J48b); 0.21, 1.0 abs (5O49)	Q_α 4.70 est, Q_β^- 1.48, Q_{EC} 0.61 est (13S53)	Th-d-2n (9G49, 4S48, 1J50); Th-α-p3n (4S48); Pa-d-p (5O49); Pa-n-γ (1J50); parent U^{232} (9G49, 5O49)
Pa^{233}	A chem, genet (1M38, 2G41, 13S41)		β^- (1M38, 2G41, 13S41)	27.4 d (2G41)	0.530, 0.430 spect (3F51); 0.5 abs (13S52); -0.2 spect, abs (21H41, 2L47, 11K50); -0.7 spect (11F44)	0.029, 0.041, 0.058, 0.076, 0.087, 0.105, 0.273, 0.302, 0.313, 0.342, 0.377, 0.400, 0.416 spect conv (11K50); 0.028, 0.040, 0.058, 0.076, 0.087, 0.105, 0.302, 0.343, 0.417 spect conv (7K51b); 0.0287, 0.0405, 0.0754, 0.0870 (rel abund 100/75/3/3) cryst spect (88B52a); 0.084, 0.298, 0.309, 0.337 spect conv (2L47); no γ >-0.4 abs (11K50)	Q_α 4.46 est, Q_β^- 0.53 (13S53)	daughter Th^{233} (1M38, 2G41, 13S41, 16H41a, 13S47a); parent U^{233} (13S47a); daughter Np^{237} (4H47); Th-d-n (4S48, 9G49); Th-α-p2n (4S48); daughter Np^{237} (15M47)
Pa^{234} (UX_2)	A chem, genet (1C31)		β^- 99+%, IT 0.15% (4F38a, 16B45)	1.175 m (112B51); 1.14 m (1C31)	2.32 (80%), 1.50 (13%), 0.60 (?) (-7%) spect (19H50); 2.32 (98%) spect (16B45)	0.817 (e_K/γ 0.04) spect conv (19H50); 0.394 (with IT, 0.15%, e/γ -1), -0.9 (-2%), -1.5 (-0.2%) spect, spect conv (16B45); 0.822, 0.806, 0.782 (weak, e/γ large) spect conv (16B43a)	Q_β^- 2.32 (16B45)	natural source, daughter Th^{234} (UX_1), parent U^{234} (U_{II})
Pa^{234} (UZ)	A chem, genet (1C31)		β^-	6.7 h (1C31)	-1.2 (10%), 0.45 (90%) spect (16B45); 1.6, 0.6 abs (4F38a)	0.85 (two γ's) abs, β-γ coinc (16B45); -0.7 (two γ's) abs, γ-γ coinc (4F38a, 4F38b)	Q_β^- 2.2 (?) est (13S53) Q_β^- 1.95 (4F49)	natural source, parent U^{234} (U_{II}); Pa^{233}-n-γ (50K52)
Pa^{235}	B chem, excit, sep isotopes (11M50); genet (20H50)		β^- (11M50, 20H50)	23.7 m (11M50); 23 m (20H50)	1.4 abs (11M50)	no γ, abs (11M50)		U^{238}-p-α, U^{238}-d-αn (11M50); daughter Th^{235} (20H50)
$_{92}U^{227}$	B chem, genet (11M52)		α (11M52)	1.3 m (11M52)	6.8 ion ch (11M52)		Q_α 7.14 est (13S53)	Th-α-9n, parent Th^{223} (11M52)
U^{228}	A chem, genet (11M49, 11M51)		α -80%, EC -20% (11M51)	9.3 m (11M51)	6.67 ion ch (7O50)		Q_α 6.79, Q_{EC} 0.30 calc (13S53)	Th-α-8n, parent Th^{224}, parent Pa^{228} (11M49, 11M51); daughter Pu^{232} (8J48)
U^{229}	A chem, genet (11M49, 11M51)		EC -80%, α -20% (11M51)	58 m (11M51)	6.42 ion ch (11M51)		Q_α 6.53, Q_{EC} 1.29 calc (13S53)	Th-α-7n, parent Th^{225}, parent Pa^{229} (11M49, 11M51)
U^{230}	A chem, genet (4S48)		α (4S48); β stable (cons energy) (HPS)	20.8 d (4S48)	5.85 ion ch (1J48); α_0 (77%), α_{70} (23%) spect (21S52)		Q_α 5.95 (13S53)	daughter Pa^{230}, parent Th^{226}, Th-α-6n (4S48); daughter Pa^{230}, Pa-d-3n, Pa-α-p4n (5O49); daughter Pu^{234} (13P49); spall U (6O47)
U^{231}	A chem, sep isotopes, excit (5O49); genet (14C50)		EC 99+%, α 5.5×10^{-3} % (14C50)	4.3 d (14C50); 4.2 d (5O49)	5.45 ion ch (14C50)	0.051, 0.064, 0.076 spect conv (8O50)	Q_α 5.55, Q_{EC} 0.34 calc (13S53)	Pa^{231}-d-2n, Pa^{231}-α-p3n (5O49); Th-α-5n (14C50, 8O50); parent Th^{227}, parent Pa^{231} (14C50)

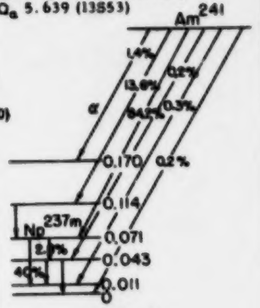
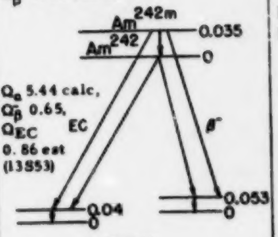
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{92}U^{232}$	A chem, genet (9G49)		α (9G49); β stable (cons energy) (HPS)	70 y yield (8J49); -30 y yield (9G49)	5. 31 range Al (1J48a); 5. 27 range air (12K44); α_0 (69%), α_{58} (31%) spect (21S52)	-0. 060 (coinc with 30% of α) α-conv coinc emuls (15D52)	Q_α 5. 40 (13S53) 	daughter Pa^{232}, parent Th^{228} (RdTh) (9G49); daughter Pu^{236} (8J49); daughter Pa^{232}, Pa^{231}-d-n, Pa^{231}-α-p2n (5O49); Th-α-4n (7N49)
U^{233}	A chem, genet (13S47a, 13S52)		α (13S52); β stable (cons energy) (HPS)	1. 62 x 10^5 y sp act + mass spect (8H52a); 1. 63 x 10^5 y sp act + mass spect (15L45); 1. 2 x 10^5 y yield (13S52)	4. 82 [illegible] C48); α_0 (8[illegible] (15%), α_{94} (2%) spec[illegible]); 4. 80 [illegible] (15C47); others [illegible]7)	0. 0428 (0.05%), 0. 0561 (0. 01%) ion ch (12W52); -0. 043, -0. 056, 0. 099 α-conv coinc emuls (113B52); 0. 04, 0. 08 (0. 8%, e/γ -8), 0. 31 (0. 1%, e/γ -3) abs (4S52); 0. 04, 0. 09, 0. 36 (all coinc with α) α-γ, α-conv coinc abs (5P51)	Q_α 4. 91 (13S53)  U233 α 2% 15% 83% 0.094 0.044 0 (HPS)	daughter Pa^{233} (13S47a); parent Th^{229} (11E47, 4H47)
U^{234} (U_{II})	A chem, genet, mass spect (1C31)	0. 0058 (1B50)	α; β stable (cons energy) (HPS)	2. 48 x 10^5 y sp act (12F52); 2. 52 x 10^5 y sp act, sp act + mass spect (13K52, 13K49); 2. 67 x 10^5 y yield (10G49); 2. 35 x 10^5 y sp act + mass spect (15C46); spont fission: 2 x 10^{16} y (13G52)	4. 763 ion ch (2C44); α_0 (74%), α_{47} (26%) spect (4A52a); 4. 76 ion ch (1S39, 13G51); 4. 78 range air (18S37), ion ch (3A47)	0 . 050, 0. 117 scint spect (17S51a); γ_1 0. 053, γ_2 0. 093, γ_3 0. 118 ($\gamma_1/\gamma_2/\gamma_3$ = 1/-0. 2/0. 4) scint spect (11B52a); 0. 055 (coinc with α, e/γ large) α-conv coinc emuls (4T52); 0. 065 (coinc with α, e/γ large) α-γ coinc abs, α-conv coinc abs (5P51); others (10M47, 17S51)	Q_α 4. 85 (13S53) 	natural source, daughter Pa^{234} (UX_2 and UZ), parent Th^{230} (Io)
U^{235} (AcU)	A chem, mass spect (1C31)	0. 715 (1B50)	α; β stable (cons energy) (HPS)	7. 13 x 10^8 y sp act (12F52); 7. 07 x 10^8 y radiogenic Pb ratios (6N39); spont fission: 1. 9 x 10^{17} y (24S52)	4. 58 (10%), 4. 47 (?) (-3%), 4. 40 (83%), 4. 20 (4%) ion ch (13G51); 4. 39 ion ch (15V52)	γ_1 0. 094, γ_2 0. 143, γ_3 0. 184, γ_4 0. 289, γ_5 0. 386 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 0. 9/0. 2/1. 0/0. 1/0. 05) scint spect (11B52a); 0. 187 abs (20S52); 0. 167 abs (10M49)	Q_α 4. 66 (13S53) U^{235}, I = 5/2 (102S50)	natural source, parent Th^{231} (UY)
U^{236}	A chem, n-capt, mass spect (9W45, 13G51a)		α (13G51a); β stable (cons energy) (HPS)	2. 39 x 10^7 y sp act (12F52); 2. 46 x 10^7 y sp act (1J51a)	4. 499 ion ch (1J51a); 4. 5 ion ch (13G51a)	-0. 050 (coinc with 27% of α) α-conv coinc emuls (15D52)	Q_α 4. 58 (13S53) 	U^{235}-n-γ (9W45, 13G51a, 1J51a)

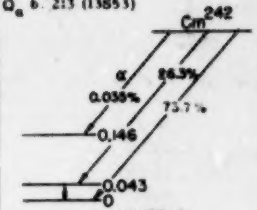
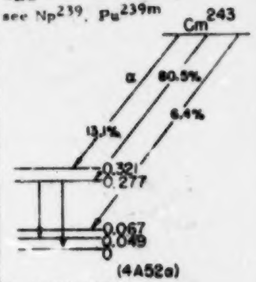
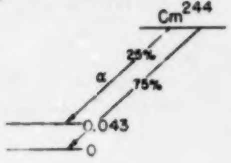
Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{92}U^{237}$	A chem, excit (5N40, 12M40)		β^- (5N40, 12M40)	6.75 d (81H52); 6.63 d (13M48); 6.8 d (1W48)	0.245, other β^- (weak) spect (3F53); ~0.23 spect (13M48)	γ_1 0.027, γ_2 0.043, γ_3 0.059, γ_4 0.165, γ_5 0.207 (α_K/γ 1.6, K/L 5.0), γ_6 0.269, γ_7 0.334, γ_8 0.370, γ_9 0.430 ($\gamma_3/\gamma_5/\gamma_7$ = 37/21/2.5) scint spect, spect conv (3F53); 0.0598 cryst spect (88B52a); 0.032, 0.057, 0.204, 0.260 abs, spect conv (13M48); 0.14, 0.23, 0.53 abs (17B43)	Q_{β}^{-} 0.514 (3F53)	U-n-2n (12M40, 5N40, 1W48, 2A44); parent Np^{237} (1W48); daughter Pu^{241} (2K45, 13S49); U-d-t (17B43, 2A44, 8J49); U-α-αn (8J49)
U^{238} (U_I)	A chem, genet, mass spect (1C31)	99.28 (1B50)	α; β stable (cons energy) (HPS)	4.49 x 10^9 y sp act (13K49); 4.51 x 10^9 y sp act (6N39); spont fission: 8.0 x 10^{15} y (24S52, 17S46)	4.18 ion ch (3A47, 2C44); 4.21 range (1S39)	~0.045 (coinc with 22% of α) α-conv coinc emuls (15D52); 0.048 (coinc with 23% of α) α-conv coinc emuls (1Z52); ~0.050 (coinc with 24% of α) α-conv coinc emuls (5A52a)	Q_{α} 4.25 (13S53)  	natural source (18B96), parent Th^{234} (UX_I)
U^{239}	A n-capt (1M37)		β^- (12M39)	23.54 m (14M43); 23.5 m (4F47, 13M47)	1.21 spect (3F53); 1.20 abs (4F47, 4F47a); 1.2 abs (1W42, 14M42); 1.12 spect (5S47)	0.0736 spect conv, scint spect (3F53); 0.073 spect conv, abs (5S47); 0.076, >0.3 (≤10%) abs (4F47, 4F47a)	Q_{β}^{-} 1.28 (3F53) Q_{α} 4.12 est (13S53)	U-n-γ (1M37, 2I39, 12M39, 22S42); parent Np^{239} (12M40a, 22S42); U-d-p (13S49a)
U^{240}	A chem, n-capt (4S49a)		β^- (4S49a)	~ 18 h genet (4S49a)				U-n-γ (second order reaction) (4S49a); parent Np^{240} (8H48b)
$_{93}Np^{231}$	A chem, genet, excit, sep isotopes (15M50)		α (15M50)	~50 m (15M50)	6.28 ion ch (15M50)		Q_{α} 6.39, Q_{EC} 1.82 calc (13S53)	U^{238}-d-9n, U^{233}-d-4n, U^{235}-d-6n, parent Pa^{227} (15M50)
Np^{232}	D chem (15M50)		EC (15M50)	~13 m (15M50)		hard γ (15M50)	Q_{α} 6.04 est, Q_{EC} 2.7 est (13S53)	U^{233}-d-3n (15M50)
Np^{233}	A chem, excit, sep isotopes (15M50, 7O51)		EC 99+%, α ~10^{-3}% (15M50)	35 m (15M50)	5.53 ion ch (15M50); conv: ~0.3 (15M50)		Q_{α} 5.63, Q_{EC} 1.09 calc (13S53)	U^{233}-d-2n, U^{235}-d-4n (15M50); U^{233}-p-n (7O51)
Np^{234}	A chem, excit, genet, sep isotopes (8J49)		EC (L/K ~1) (7O51a); no α (lim 0.01%) (8H49); no β^+ (8H49)	4.40 d (8H49); 4.4 d (5O49)		0.177, 0.442, 0.803, 1.42 spect conv (7O51a); 1.9 abs (8H49, 5O49)	Q_{α} 5.39 est, Q_{EC} 1.8 est (13S53)	U^{235}-d-3n, U^{235}-α-p4n (8J49); U^{235}-p-2n (11G46); U^{233}-d-n (8H49); U^{233}-α-p2n (8H49, 13P49); Pa^{231}-α-n (5O49); daughter Pu^{234} (13P49)
Np^{235}	A chem, excit, sep isotopes (8J49)		EC (L/K >9) (8J52); α ~5 x 10^{-3}% (8J52)	410 d (8J52)	5.06 ion ch (8J52)		Q_{α} 5.15, Q_{EC} 0.17 calc (13S53)	U^{235}-d-2n (8J49, 8J52); U^{233}-α-pn (8H49)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{93}Np^{236}$	A chem, genet, sep isotopes, excit (8J49)		β^- -33%, EC -67% (L/K -2) (7O51b)	22 h (8J49)	0.51 (-60%), 0.36 (-40%) spect (7O51b)	0.150 (e/γ large) spect conv (7O51b)	Q_α 5.00 est, Q_β^- 0.63 est, Q_{EC} 1.03 est (13S53)  see Am^{241} (7O51b)	U^{235}-d-n, U^{235}-α-p2n, U-d-4n (8J49); Np^{237}-d-p2n (8J49a); U^{233}-α-p (8H49); Np^{237}-n-2n (13G48, 13F50); parent Pu^{236} (8J49, 8J49a, 8H49, 13G52)
Np^{237m}	A genet (103B52)		IT (103B52)	6.3×10^{-8} s delay coinc (103B52)		0.060 scint spect (103B52)		daughter Am^{241} (103B52)
Np^{237}	A chem, genet, excit (1W48)		α (1W48); β stable (cons energy) (HP5)	2.20×10^6 y sp act (15M48)	4.77 ion ch (13G48c)	soft γ's (coinc with 80% of α) α-conv coinc emuls (15D52); soft γ, spect conv (15M45)	Np^{237}, I = 5/2 (87M50) Q_α 4.97 est (13S53)	daughter U^{237} (1W48); parent Pa^{233} (15M47)
Np^{238}	A chem, genet, n-capt, sep isotopes (13S46)		β^- (13S46, 13S49a)	2.10 d (3F50a); 2.0 d (13S49a)	1.272 (47%), 0.258 (53%) spect, spect coinc (3F50a); 1.39, 0.22 abs (1J49)	0.043, 0.047, 0.103 (L/M 1.6), 0.983, 1.03 (1.03 γ/0.98 γ = 1) spect, spect conv, β-γ, β-x coinc (3F50a); no 0.047 γ (63M52a, 4A52a); 1.1 abs (13S49a); 0.075, 1.2 abs, abs conv (1J49)	Q_α 4.83 est, Q_β^- 1.42, Q_{EC} 0.38 est (13S53) see Cm^{242}  Np^{238} Cm^{242} 53% 47% β^- 1.13 0.035% α 26.3% 73.7% 0.146 0.104 (2+) (0+) 0.043 0 (4A52a)	U-d-2n (13S46, 13S49a, 14K49); U^{238}-d-2n (14K49); parent Pu^{238} (13S46, 14K49, 1J49, 8J49); daughter Am^{242} (13S49, 68S0a); U^{238}-α-p3n, U^{235}-α-p (8J49); Np^{237}-n-γ (1J49); Np^{237}-d-p (8J49a)
Np^{239}	A chem, n-capt, genet, excit (12M39, 12M40a)		β^- (12M40a)	2.33 d (1W42); 2.35 d (4F42); 2.3 [illegible] (3P46)	0.715, 0.654 0.44, 0.33 spect (7T51); 0.718 (4.8%), 0.655 (1.7%), 0.441 (31%), 0.380 (10%), 0.329 (52%) spect (3F53); 0.705 (7%, not coinc with γ), 0.435 (46%), 0.310 (47%) spect (14G51); 1.179, 0.676, 0.403, 0.288 spect (5S47); others (22H45, 11F49)	0.049, 0.057, 0.061, 0.067 (coinc with 0.210 γ), 0.210, 0.227, 0.276 (last 3 γ's coinc with 0.435 β^-, 0.276 γ not coinc with 0.227 γ) spect conv, β-γ, γ-γ coinc (14G51); 0.013, 0.019, 0.044, 0.049, 0.057, 0.061, 0.067, 0.077, 0.105, 0.209, 0.228, 0.254, 0.277, 0.285, 0.316, 0.334 spect conv (3F53); 0.044, 0.049, 0.057, 0.061, 0.068, 0.105, 0.209, 0.228, 0.254, 0.277, 0.286 spect conv (7T51); 0.023, 0.049, 0.057, 0.061, 0.068, 0.106, 0.209, 0.228, 0.277 spect conv (11F49); 0.0576, 0.0618 cryst spect (26J52); 0.057, 0.061, 0.067, 0.206, 0.227, 0.275 spect conv (5S47); others (4F42, 22H45, 3P46)	Q_β^- 0.715 (3F53, 14G51)  Np^{239} Cm^{243} β^- α 13.1% 80.5% 6.4% Pu^{239m} 0.382 0.334 0.321 0.277 0.067 0.049 0 (4A52a)	daughter U^{239} (12M40a, 22S42); parent Pu^{239} (14K46, 13S49a); U-d-n (13S46, 13S49a, 8J49); U-α-p2n (8J49); daughter Am^{243} (68S0a)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{93}Np^{240}$	A chem, genet (8H48b)		β^- (8H48b)	7.3 m (8H48b)	-1.3 abs (8H48a)			daughter U^{240} (8H48b)
Np^{241}	B chem, cross bomb (7O51a)		β^- (7O51a)	60 m (7O51a)	0.89 spect (7O51a)	0.15, 0.20, 0.26, 0.58 spect conv (7O51a); -0.7 abs (7O51a)		U^{238}-α-p (7O51a)
$_{94}Pu^{232}$	B chem, sep isotopes, excit, genet (7O51a)		α ≥2%, EC ≤98% (7O51a)	36 m (7O51a)	6.58 ion ch (7O51a)		Q_α 6.70, Q_{EC} 0.96 est (13S53)	U^{235}-α-7n, U^{233}-α-5n, parent U^{228} (7O51a)
Pu^{234}	A chem, genet, sep isotopes, excit (8H49, 13P49)		α ~4%, EC ~96% (7O51a, 23H52a)	9.0 h (7O51a); 8.5 h (13P49)	6.19 ion ch (7O51a); 6.2 ion ch (13P49)		Q_α 6.30, Q_{EC} 0.21 est (13S53)	U^{233}-α-3n (8H49, 13P49, 7O51a); U^{235}-α-5n (7O51a); parent U^{230}, parent Np^{234} (13P49, 7O51a); daughter Cm^{238} (23H52a)
Pu^{235}	B chem, excit, sep isotopes (7O51a)		EC 99+%, α ~0.002% (7O51a)	26 m (7O51a)	5.85 ion ch (7O51a)		Q_α 5.95, Q_{EC} 1.14 calc (13S53)	U^{233}-α-2n, U^{235}-α-4n (7O51a)
Pu^{236}	A chem, excit, sep isotopes, cross bomb, genet (8J49)		α (8J49); β stable (cons energy) (HPS)	2.7 y (8J49); spont fission: 3.5×10^9 y (13G52)	5.75 range air (8J49); 5.75 ion ch (13G53)	~0.045 (coinc with 20% of α) α-conv coinc emuls (15D52)	Q_α 5.85 (13S53)  Pu^{236} ~20% α ~80% 0.045 0 (HPS)	U^{235}-α-3n, U^{238}-α-6n (8J49); Np^{237}-d-3n (8J49a); U^{233}-α-n (8H49, 13P49); daughter Cm^{240} (13S49b); daughter Np^{236} (8J49, 8J49a, 8H49, 13G52)
Pu^{237}	B chem, sep isotopes, cross bomb (8J49)		EC (8J49)	~40 d (8J49)		K, L-x, no γ (8J49)	Q_α 5.72 est, Q_{EC} 0.21 est (13S53)	U^{235}-α-2n, U-α-5n (8J49); Np^{237}-d-2n (8J49a)
Pu^{238}	A chem, sep isotopes, excit (13S46, 13S46a, 13S49a)		α (13S46); β stable (cons energy) (HPS)	89.6 y (1J56a); 92 y genet (13S49b); 77 y genet (1J49); spont fission: 3.8×10^{10} y (24S52)	5.492 (76%), 5.450 (24%) spect (4A52a); 5.47 range air (8T49); 5.51 range air (15C47)	0.045 spect conv (8O51); ~0.040 (coinc with 23% of α) α-conv coinc emuls (15D52); ~0.04 (e/γ ~700) α-γ coinc, scint spect (4A52d)	Q_α 5.586 (13S53)  Pu^{238} 24% α 76% (2+) (0+) 0.045 0 (HPS)	U^{238}-d-2n (13S46, 13S49a, 14K49, 7E42, 8J49); U^{238}-α-4n, U^{235}-α-n (8J49); daughter Np^{238} (8J49, 1J49, 13S46a, 14K49); daughter Cm^{242} (13S49b)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{94}Pu^{239m}$	A genet (14G51)		IT (14G51)	1.1 x 10^{-9} s delay coinc (14G51)		0.049 0.067, 0.210, 0.227, 0.276 spect conv, coinc (14G51)	see Np^{239}, Cm^{243}  (14G51)	daughter Np^{239}, parent Pu^{239} (14G51)
Pu^{239}	A chem, genet, mass spect (14K46)		α (14K46); β stable (cons energy) (HPS)	24,360 y sp act (10W51); 24,400 y sp act (11W46, 14F45); 24,300 y sp act (16C49); 24,100 y calorimetric (96847); spont fission: 5.5 x 10^{15} y (24S52)	5.150 (69%), 5.137 (20%), 5.099 (11%) spect (4A52e); 5.147 (~70%), 5.097 (~30%) spect (4R50); 5.14 ion ch (10J48); 5.15 range air (15C47); 5.13 ion ch (17C51); 5.13 range air (8T49); conv: ~0.10 (weak) e-conv coinc emuls (15D52, 5A51)	γ_1 0.039, γ_2 0.0531, γ_3 0.100, γ_4 0.124, γ_5 0.384 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 0.4/1.4/1.1/0.5/0.3) spect conv, scint spect (3F52b); 0.0385 (2 x 10^{-3}%), 0.0520 (7 x 10^{-3}%) ion ch (12W51, 12W52); ~0.035, 0.05 e-conv coinc emuls (15D52); 0.05 e-conv coinc emuls (5A51); others (11S2)	Q_α 5.238 (13S53)  Pu^{239} 11% 69% α 20% 0.051 0.013 0(?) (4A52a, HPS)	daughter Np^{239} (14K46, 13S49a); U^{238}-α-3n (8J49); Pu^{238}-n-γ (9R48, 19B48)
Pu^{240}	A chem, n-capt, mass spect (15C44, 14F46, 21B44)		α (8J49); β stable (cons energy) (HPS)	6580 y genet (3I51); 6240 y sp act (11W51); 6760 y sp act (10W51)	5.162 (76%), 5.118 (24%) spect (4A52e)	0.0496 spect conv, scint spect (3F52b)	Q_α 5.250 (4A52e)  (4A52e)	Pu^{239}-n-γ (15C44, 14F46, 21B44); U^{238}-α-2n (8J49)
Pu^{241}	A chem, n-capt, mass spect, excit, genet (13S49, 13S49b, 13G50)		β^- 99+%, α ~10^{-3}% (13S49, 3T50e)	14 y genet (3T50e)	α: 4.91 ion ch (3T50e); β^-: 0.021 spect (3F52b); ~0.02 abs (13S49)	γ_1 0.100, γ_2 0.145 (γ_1/γ_2 = 5) scint spect (3F52b)	Q_α 5.15, Q_β^- 0.021 (13S53)	Pu^{240}-n-γ (13G50, 3T50e); U^{238}-α-n (13S49); parent Am^{241} (13S49, 16C49a); parent U^{237} (2K45, 13S49)
Pu^{242}	A chem, mass spect, n-capt, genet (3T50e)		α (3T50e); β stable (cons energy) (HPS)	~5 x 10^5 y genet (3T50e)	4.88 ion ch (3T50e)		Q_α 4.96 (13S53)	Pu^{241}-n-γ (3T50e, 3I49); daughter Am^{242m} (8O50a)
Pu^{243}	B chem, n-capt, cross bomb (25S51)		β^- (25S51)	4.98 h (81H52a); 5.0 h (25S51, 3T51)	0.39 spect (3T51); ~0.45 abs (25S51)	0.095, 0.12 spect conv (3T51)	Q_α 4.82 est, Q_β^- 0.67 est (13S53)	Pu^{242}-n-γ (25S51, 3T51); parent Am^{243} (3T51)
$_{95}Am^{237}$	B chem, excit (23H52a)		EC 99+%, α 0.005% (23H52a)	~1.3 h (23H52a)	6.01 ion ch (23H52a)		Q_α 6.20 est, Q_{EC} 1.6 est (13S53)	Pu^{239}-d-4n, Pu^{239}-p-3n (23H52a)
Am^{238}	B chem, excit (6S50a)		EC (6S50a); no α (lim 3 x 10^{-4}%) (23H52a)	2.1 h (23H52a)	conv (6S50a)		Q_α 5.99 est Q_{EC} 2.22 est (13S53)	Pu^{239}-d-3n (6S50a, 23H52a)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{95}Am^{239}$	B chem, excit (13S49)		EC 99+%, α 0.003% (23H52a)	12 h (13S49)	5.75 ion ch (23H52a)	0.3 (10%) scint spect (23H52a); 0.3 abs conv (13S49)	Q_α 5.85, Q_{EC} 0.78 calc (13S53)	Np^{237}-α-2n (13S49); Pu^{239}-p-n (6S50a); Pu^{239}-d-2n (13S49, 23H52a); Pu^{239}-α-p3n (23H52a)
Am^{240}	B chem, excit (13S49); chem, excit, cross bomb (6S50a)		EC (13S49); no α (lim 0.2%) (23H52a)	50 h (13S49); 53 h (23H52a)		no γ >0.7 (23H52a)	Q_α 5.76 est, Q_β^- 0.02 est, Q_{EC} 1.54 est (13S53)	Np^{237}-α-n (13S49); Pu^{239}-d-n (13S49, 6S50a, 23H52a); Pu^{239}-α-p2n (23H52a)
Am^{241}	A chem, n-capt, excit, mass spect (13S49)		α (13S49); β stable (cons energy) (HPS)	470 y sp act (20H52a); 475 y sp act (16C50)	5.546 (0.23%), 5.535 (0.34%), 5.503 (0.21%), 5.476 (84.2%), 5.433 (13.6%), 5.379 (1.4%) spect (4A52); 5.48 ion ch (13G48c); 5.47 range air (8T49)	γ_1 0.0597 (40%, e/γ ≤1.5, with Np^{237m}), γ_2 0.0263 (2.8%, e/γ ≤20), γ_3 0.0209, γ_4 0.0173, γ_5 0.0135 ($\gamma_1/\gamma_2/\gamma_3/\gamma_4/\gamma_5$ = 1/0.069/0.155/0.56/0.32) ion ch, α-γ delay coinc (103B52); γ_1 0.0598, γ_2 0.0264, (γ_1/γ_2 = 1/0.30 0.05/0.10) cryst spect (88B52a); 0.0590, 0.0414, 0.0264 spect conv, scint spect (3F52b); others (13S49, 8O51, 5P51, 15D52)	Am^{241}, I = 5/2 (38F52) Q_α 5.639 (13S53)  Am241 1.4% 0.2% 13.6% 84.2% 0.3% α 0.170 0.2% 0.114 Np237m 2.8% 0.071 0.043 40% 0.011 0 (103B52)	daughter Pu^{241} (13S49, 16C49a); parent Np^{237m} (103B52)
Am^{242m}	A chem, n-capt, genet (16M49, 13S49b)		β^- 60%, EC (L) 20%, IT 20% (8O51)	16.01 h (44K52); 15.7 h (20H49a); 16 h (16M49)	0.628 spect (8O50a); 0.63 abs (15G50)	0.035, 0.038, 0.053 spect conv (8O51)	Q_β^- 0.68 (HPS)	Am^{241}-n-γ (16M49, 13S49); parent Cm^{242} (16M49, 13S49b); parent Pu^{242} (8O50a)
Am^{242}	A chem, genet, mass spect, n-capt (13S49, 6S50a)		β^-, EC, α (8O51); (α/β^- 0.01) (6S50a)	~100 y genet (6S50a)	β^-: 0.593 spect (8O51); ~0.5 abs (13S49)	0.038, 0.053 spect conv (8O51)	 Am242m 0.035 Am242 0 EC β- 0.04 0 0.053 0 Q_α 5.44 calc, Q_β^- 0.65, Q_{EC} 0.86 est (13S53) (8O51)	Am^{241}-n-γ, parent Cm^{242}, parent Np^{238} (13S49, 6S50a, 13S49b)
Am^{243}	A chem, mass spect (6S50a)		α (6S50a)	~10^4 y genet (6S50a)	5.267 (~90%), 5.226 (~10%) spect (4A52a); 5.27 ion ch (13G51b)	0.075 (coinc with 90% of α) α-γ coinc, scint spect (4A52a); 0.076 scint spect (89M52a)	Q_α 5.430, Q_β^- 0.00 calc (13S53)	Am^{242}-n-γ, parent Np^{239} (6S50a); daughter Pu^{243} (3T51)
Am^{244}	B chem, n-capt (6S50a)		β^- (6S50a)	~25 m (6S50a)				Am^{243}-n-γ (6S50a)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma transitions		
$_{96}Cm^{238}$	B chem (6S48a); chem, genet (23H52a)		EC <90%, α >10% (75C52)	2.5 h (6S48a)	6.50 ion ch (6S48a)		Q_α 6.61, Q_{EC} 0.8 est (13S53)	Pu^{239}-α-5n (6S48a); parent Pu^{234} (23H52a)
Cm^{239}	D chem, excit (75C52)		EC ~100%, no α (lim 0.1%) (75C52)	~3 h (75C52)			Q_α 6.50 est, Q_{EC} 1.8 est (13S53)	Pu^{239}-α-4n (75C52)
Cm^{240}	A chem, genet (13S49b)		α (13S49b); no EC (lim 0.5%) (23H52)	26.8 d (13S49b); spont fission: 7.9 x 10^5 y (13G52)	6.25 ion ch (23H52); 6.3 range air (13S49b)		Q_α 6.37 (13S53)	Th-C-4n (23H52a); Pu^{239}-α-3n (13S49b, 23H52)
Cm^{241}	B chem, excit (13S49b, 23H52)		EC 99+%, α 0.2% (23H52a)	35 d (23H52)	5.90 ion ch (23H52a)		Q_α 6.3 est, Q_{EC} 0.9 est (13S53)	Pu^{239}-α-2n, Am^{241}-p-n (23H52, 23H52a)
Cm^{242}	A chem, genet (13S49b); mass spect (10R50)		α (13S49b); β stable (cons energy) (HPS)	162.5 d (24H50); 162 d (8J48a); spont fission: 7.2 x 10^6 y (24H51)	6.110 (73.7%), 6.066 (26.3%), 5.965 (0.035%) spect (4A52, 4A52d); 6.118 ion ch (20H52); 6.08 ion ch (13G48c)	0.043 spect conv (8O51); ~0.04 (e/γ ~600) e-γ coinc, scint spect (4A52d); ~0.045 (coinc with 23% of α) α-conv coinc emuls (15D52); ~0.04 (coinc with α) α-conv coinc (5P51)	see Np^{238} Q_α 6.213 (13S53)  Cm242 α 26.3% 0.035% 73.7% 0.146 0.043 0 (4A52a)	Pu^{239}-α-n (13S49b); daughter Am^{242} (13S49b, 13G50); Am^{241}-d-n (3T50a); daughter Cf^{246} (25H51)
Cm^{243}	A chem, mass spect, genet (10R50)		α (10R50)	~100 y genet (3T50b)	5.985 (6.4%), 5.777 (80.5%), 5.732 (13.1%) spect (4A52d); 5.89 (15%), 5.79 (85%) ion ch (3T50b)	0.226, 0.277 (both γ's coinc with 5.777 α) scint spect (4A52d)	Q_α 6.15 (4A52a) Q_{EC} 0.00 calc (13S53) see Np^{239}, Pu^{239m}  Cm243 α 80.5% 6.4% 13.1% 0.321 0.277 0.067 0.049 0 (4A52a)	Cm^{242}-n-γ (10R50); daughter Bk^{243} (3T50b)
Cm^{244}	A chem, mass spect (10R50)		α (10R50); β stable (cons energy) (HPS)	19 y (3T52); spont fission: 1.4 x 10^7 y (13G52)	5.798 (75%), 5.755 (25%) spect (4A52d)		Q_α 5.895 (13S53)  (HPS)	daughter Am^{244}, Cm^{243}-n-γ (10R50)
Cm^{245}	B chem, decay charac, genet (25H51)		α (25H51)	>500 y (25H51)	~5.6 ion ch (25H51)			daughter Bk^{245} (25H51)

Isotope Z A	Class and identification	Percent abundance	Type of decay	Half-life	Energy of radiation in Mev		Disintegration energy and scheme	Method of production and genetic relationships
					Particles	Gamma-transitions		
$_{97}\mathrm{Bk}^{243}$	A chem, n-capt, genet (3T50, 3T50b)		EC 99+%, α ~0.1% (3T50b)	4.6 h (3T50b)	6.72 (30%), 6.55 (53%), 6.20 (17%) ion ch (3T50b)		Q_α 6.83, Q_{EC} 1.46 calc (13S53)	Am^{241}-α-2n (3T50, 3T50b); Cm^{242}-d-n (25H51); parent Cm^{243} (3T50b)
Bk^{244}	D chem, decay charac (3T52)		EC (3T52)	~5 h (3T52)			Q_α 6.63 est, Q_{EC} 2.27 est (13S53)	Am^{241}-α-n (3T52)
Bk^{245}	B chem, excit, decay charac (25H51)		EC 99+%, α ~0.1% (25H51)	4.95 d (25H51)	6.33 (18%), 6.15 (48%), 5.90 (34%) ion ch (25H51)		Q_α 6.44, Q_{EC} 0.67 est (13S53)	Am^{243}-α-2n (3T52); Cm^{244}-d-n, Cm^{242}-α-p (25H51); parent Cm^{245} (25H51)
$_{98}\mathrm{Cf}^{244}$	B chem, excit, decay charac (3T50c)		α, EC (?) (3T50d)	45 m (3T50d)	7.15 ion ch (3T50d)		Q_α 7.27, Q_{EC} 0.7 est (13S53)	U-C-6n (13G51c); Cm^{242}-α-2n (3T50c, 3T50d)
Cf^{246}	A chem, genet (13G51c)		α (13G51c); β stable (cons energy) (HP5)	35.7 h (25H51) spont fission: ~2000 y (25H53)	6.75 ion ch (13G51c)		Q_α 6.86 (13S53)	U-C-4n (13G51c); Cm^{243}-α-n, Cm^{244}-α-2n (25H51); parent Cm^{242} (25H51)

RAPID METHOD FOR CALCULATING LOG (ft) VALUES

from S. A. Moszkowski, Phys. Rev. 82, 35 (1951)

The following figures permit the rapid calculation of log (ft) for a given type of decay, given energy, half-life, etc. The notation is: E_0 for $\beta^{\pm}$ emission is the maximum kinetic energy of the particles in Mev; E_0 for K electron capture is the disintegration energy in Mev. When a β^+ emission and K electron capture go from and to the same level, E_0 for K capture = E_0 for β^+ emission + 1.02 Mev. Z is the atomic number of the initial nucleus, t is the total half-life, and p is the percentage of decay occurring in the mode under consideration. When no branching occurs, p = 100.

Procedure for obtaining log (ft)

(1) First obtain log (f_0t), using Fig. 1. E_0 is read off the left-hand side of the E_0 column for K electron capture, and off the right-hand side for $\beta^{\pm}$ emission. Put a straight edge over the given values of E_0 and t and note where it crosses the column of log (f_0t) values.

(2) Then read off log (C) from Figs. 2, 3, and 4 for β^-, β^+, and K electron capture, respectively.

(3) Get Δ log (ft) from Fig. 5 if $p < 100$. When p = 100, Δ log (ft) = 0.

(4) Log (ft) = log (f_0t) + log (C) + Δ log (ft).

These graphs have been reproduced with the kind permission of Dr. Moszkowski. For details concerning their construction, significance, and range of usefulness, reference should be made to the original paper.

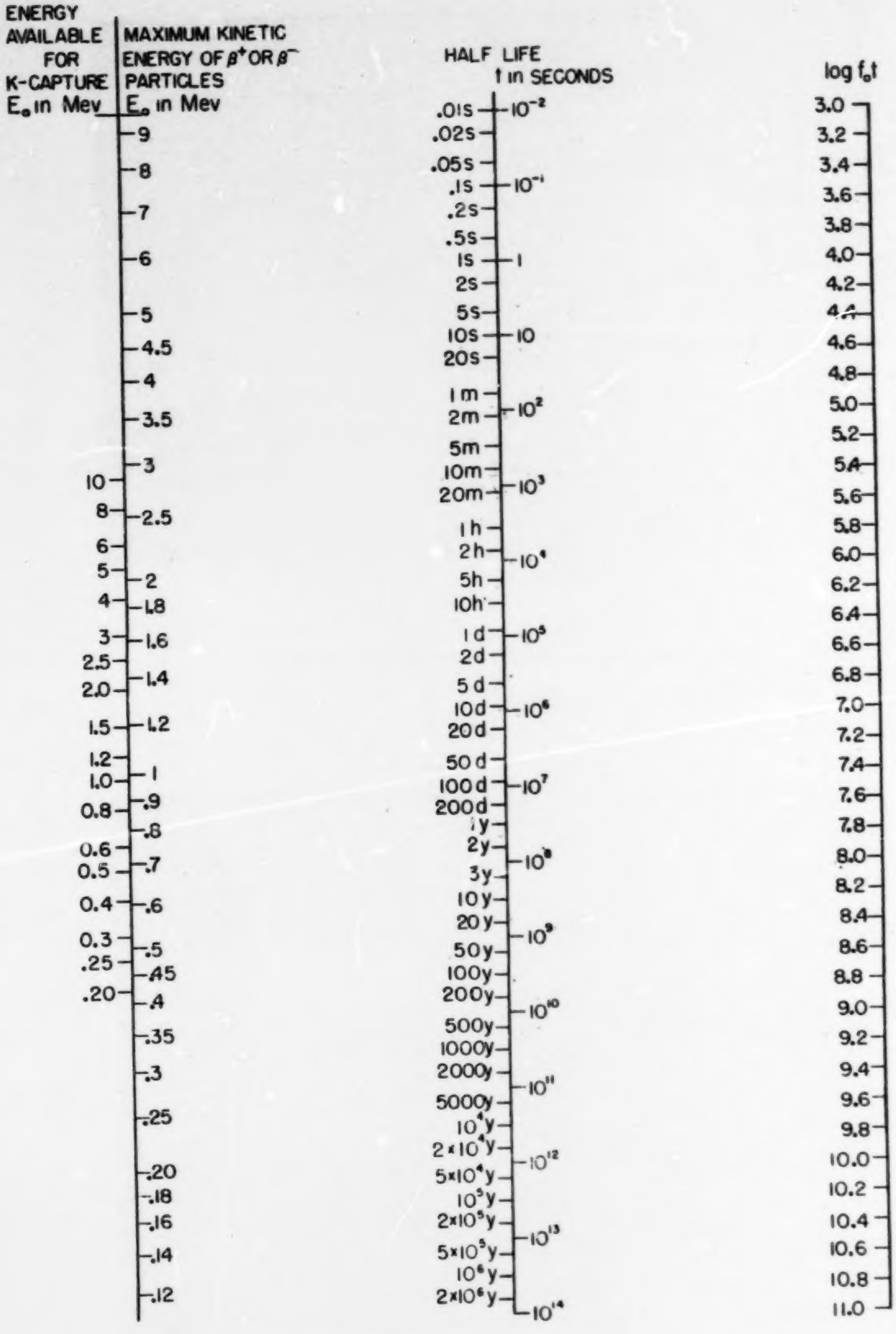


Fig. 1. Log (f_0t) as a function of E_0 and t

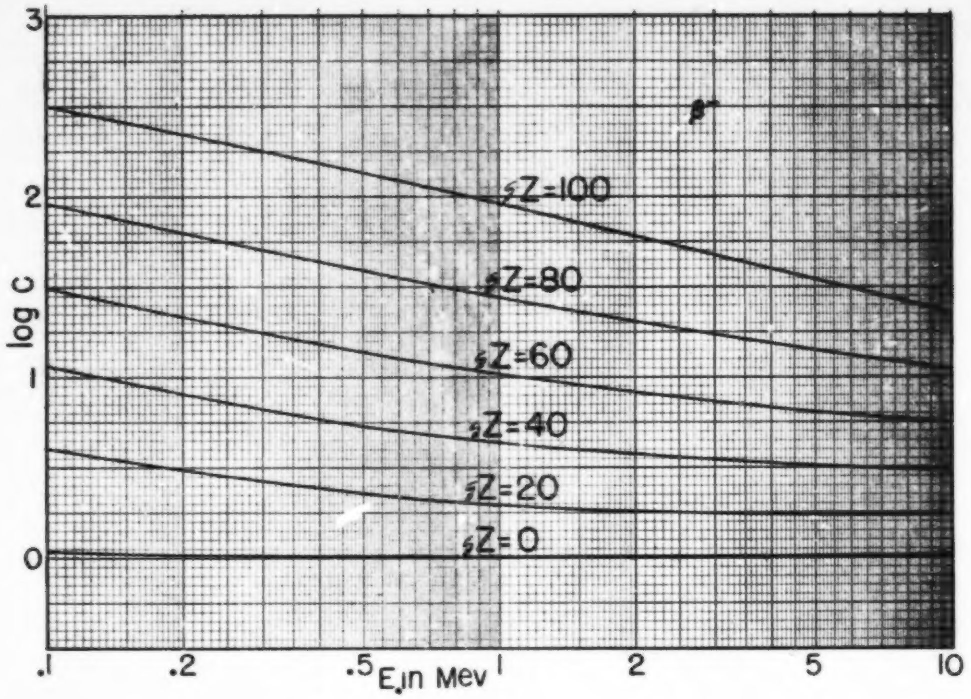


Fig. 2. Log (C) as a function of E_0 and Z for β^- emission.

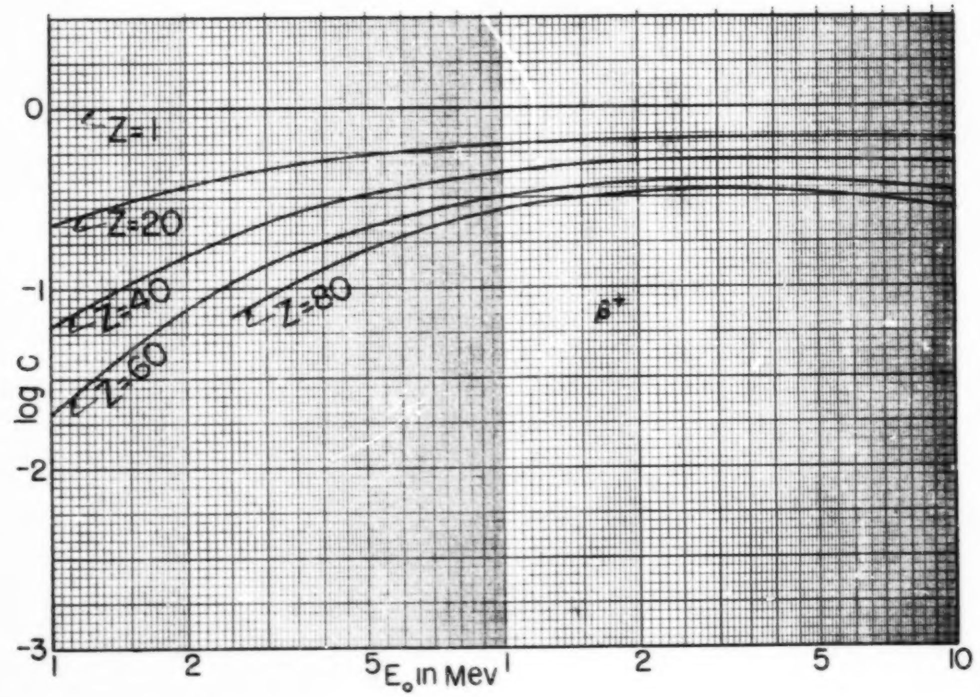


Fig. 3. Log (C) as a function of E_0 and Z for β^+ emission.

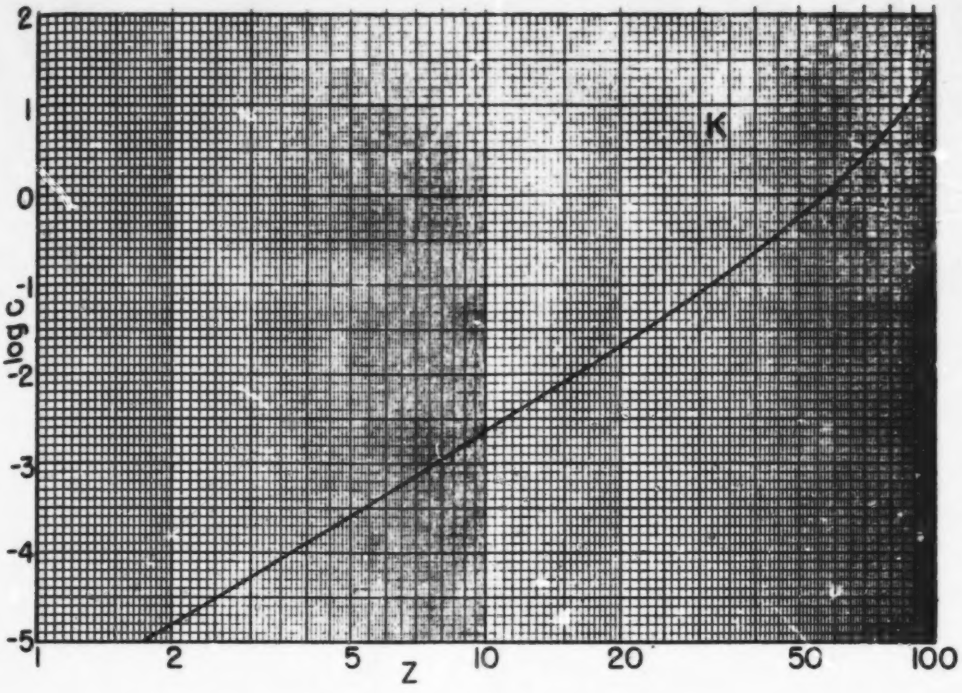


Fig. 4. Log (C) as a function of Z for K electron capture.

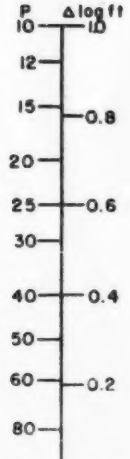


Fig. 5. Δ log (ft) as a function of p.

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